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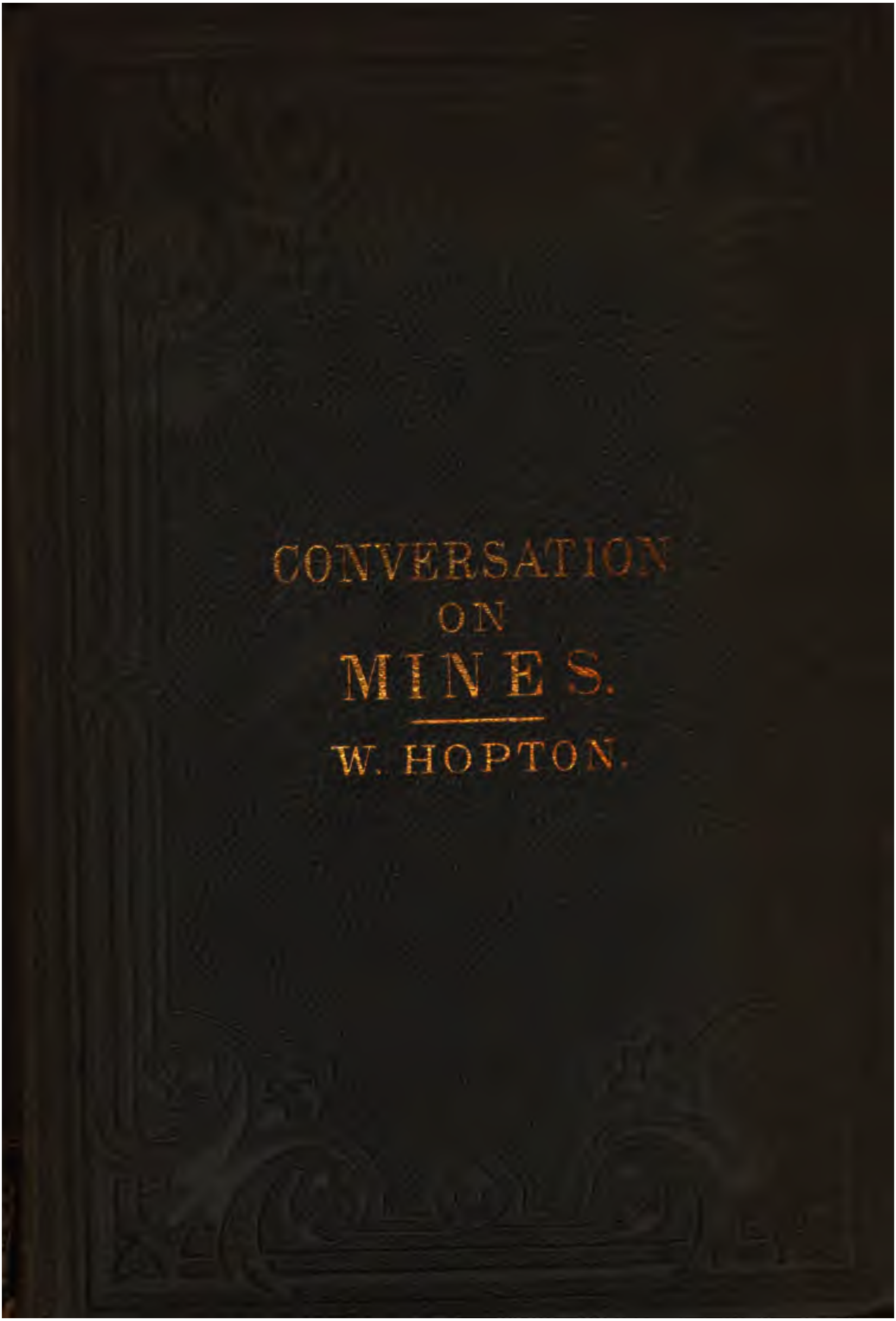


CONVERSATION ON MINES.

W. HOPTON.

A

CONVERSATION ON MINES,

&c.,

BETWEEN A FATHER AND SON,

BY WILLIAM HOPTON,

COLLIERY MANAGER, ST. HELENS, LANCASHIRE,

Author of "The Lund Hill Mode of Ventilation;" and "Practical Treatise on Gases, Explosions, Ventilation, and the Workings of Mines."

St. Helens, March 14, 1864,

The undermentioned persons have examined the Plans, &c., connected with the work, and have unanimously pronounced them to be of great practical utility, and the work to be one which has hitherto been much needed by Miners at large.

JAMES JERVIS,	ROBERT WOODWARD,
THOMAS HURST,	FRANCIS LYNN,
ROBERT KENYON,	THOMAS ROSBOTTOM,
ALFRED MICKLETHWAITE,	GEORGE PENNINGTON.

MANCHESTER:
ABEL HEYWOOD AND SON, 56 & 58, OLDHAM STREET.
1864.
Price Two Shillings and Sixpence.

198. g. 3.

A CONVERSATION ON MINES.

Son: Had you much pain, just before you were struck insensible; or you remember very little of what took place?—Father: I remember well; I had no pain, and I was very sick for may be a moment, just before I lost all knowledge of things. My limbs also felt very heavy.

Son: Would you then be like a person insensible with sleep; as a person knows not the moment they pass away into sleep, I presume you in like manner would have no knowledge of the time, and moment, you passed into insensibility. But how long were you in that state of unconsciousness?—Father: I cannot tell how long I was insensible, as I was at home, brought up out of the pit, when I came to a proper knowledge of things; and when at home, long before my knowledge of things returned properly, every person I could see appeared as in a dream.

Son: By this, I presume, father, all persons lost by explosions, with after-damp, will suffer very little at death, as they will pass away like a person in a sleep?—Father: I believe they know very little until death pass them away into eternity; as I know had I remained in the pit a little longer, I should have passed away without a knowledge of the case.

Son: Will explosive gas ignite if not mixed with atmospheric air?—Father: No. One foot of explosive gas requires a mixture of from five to twelve feet of air to cause it to ignite.

Son: Do not miners' candles burn with enlarged flames, when working where explosive gas accumulates?—Father: The flame of the candle is enlarged when air and gas is near the explosive mixture. When one foot of gas is mixed with only 13, 14, 15, or 16 feet of air, the candle burns with enlarged flame; but by mixing more air to the one foot of gas, the flame of the candle diminishes to its proper size.

Son: What quantity of air does gas require to make it, *when ignited,* at the greatest explosive mixture or power?—Father: One foot of gas mixed with seven feet of air will be near the greatest explosive mixture.

Son: If a miner's working place is full of gas, will not air annihilate or destroy the gas therein if mixed with it?—Father: No; air will not destroy gas, but only render it harmless by a larger mixture of air than gas.

Son: Is explosive gas elastic?—Father: Yes. Three feet of gas may be pressed into the space of one foot; and, if the pressure be reduced sufficiently, the three feet will expand into six feet or more.

Son: Then when the weight is reduced from the gas, the gas expands out of the strata—out of every hole in the roof, and out of old gobs, which may be called magazines of gas, and overflows into the workings and tramroads from every place wherein it is compressed?—Father: Yes; that's the cause of mines accumulating more gas at one time than at another, and also more when a change takes place in the weather.

Son: Why does explosive gas make its way up to the roof in mines, and fill holes and stock-working places which lie highest?—Father: Because explosive gas is much lighter than air. Two feet of the gas will weigh only a little more than one foot of air.

Son: Why does carbonic acid gas, which miners call black-damp, lay nearest the floor in mines?—Father: Because it is heavier than air. One foot of black-damp will weigh very nearly two feet of air, its greater weight being the cause of its laying nearest the floor.

Son: If damp be heavier than air, how can air drive it away, or force it along through the workings and up the up-cast? Will not air pass through, and the gas settle downwards to the bottom like mud in water?—Father: Unless air pass through the workings and up the up-cast with such a velocity or speed, as to have a force greater than the weight of black-damp, it will settle downwards through the air like mud in water, and not be got up out of a mine.

Son: What is meant by generating, producing, and accumulating; that is, what am I to understand, father, by the same, as I often hear people say mines generate, produce, and accumulate gases?—Father: What you may understand by the word "generate," is to produce from, to bring from, or, to cause. Also, the word "accumulate," is to add to, to produce, to multiply, to increase, to collect, or, to make more.

Son: But how are gases then, father, generated, produced, or accumulated in mines?—Father: There are two ways by which gases may be said to accumulate in mines. All gases are generated or produced, you know, from every stratum, from one end of the whole route of the air-passage to the other. When the air first enters the air-gate, at the down-cast, there is in the first yard of its route a supply of gases. More gases are added to the same as the air passes onwards. Pass the air forward, and the quantity of gases in it multiplies; yet, as the air goes onward, the flow of gas from every stratum increases, until the same is discharged at the top of the up-cast. This is one way by which gases accumulate; but, the other is, when air cannot get at and around any stocked or undisturbed parts of the mine to bring gas out and away therefrom; and also when or if the air in mines should, at any time, be stagnant, such mine would very soon fill with gases, by which the accumulation of gases would at once take place.

Son: In those mines, then, where much gas is produced, and there is not a proper quantity of air to dilute it, the accumulation will be very great.—Father: Yes; there is always an accumulation of gas going on in mines, especially if the quantity of air be not sufficient to dilute and render it harmless.

How Gases are Generated, Accumulated, and Produced in Mines.

Son: Is there any weight on the strata of coal and stone from where gas is produced, to compress the said gas therein? Father: There is the atmospheric weight or pressure always pressing against the strata from whence it generates.

Son: What is the pressure of the atmosphere against the strata?—Father: The pressure is nearly 15lbs. upon every square inch of the strata or surface.

Son: Is the amount of gas generating in mines then *in proportion* to its overbalancing pressure?—Father: Yes. The accumulation of gas in mines is like steam blowing away from a boiler. When steam is much compressed in a boiler the compressed steam will lift up the weight of the valve which presses it there, and it will continue to blow away therefrom until its compression is reduced to the weight of the valve; in like manner, gas blows out and generates from the strata because its compression therein is greater than the weight of the atmosphere.

The Cause, or, why it is that one Mine Generates and Produces more Gases than another.

Son: Why does one mine make or accumulate more gas than another?—Father: Because the compression of gas is greater in one mine than in another.

Son: Why do not all mines make explosive gas alike in quantity, when the atmospheric weight is equally alike reduced from the strata in all mines?—Father: The atmospheric weight is alike reduced from the strata, but the "compression" of gas is not alike in all mines; therefore, the accumulation of gas is not equally alike.

Son: I cannot see why all mines do not accumulate gas alike, when the weight which presses in the gas is reduced alike in all.—Father: Well, I will illustrate the case. Suppose three boilers to be full of steam, the weight on each valve 15lbs., the steam in one boiler so compressed, that a great quantity of steam blows off, another, not so compressed, blows off less steam, and a third blows off very little, because little compressed. Now, by taking 1lb. weight from each valve, the greatest quantity of steam will blow off from the one most compressed; so, in like manner, will most gas accumulate in those mines where it is most compressed.

Son: Why is not the pressure of gas in mines alike?—Father: Because the gas has been blowing off longer in some than in others.

Son: Will not the great pressure of gas in the strata all blow off in time, as steam will all blow off from a boiler, until the pressure of gas be the same as the pressure of the atmosphere?—Father: In time the two will become alike equal in pressure.

Son: By this I understand the pressure of gas in the strata will become so reduced that it will press out with only a 15lb. pressure, like the 15lb. pressure of the atmosphere which presses it there, the two then being equal?—Father: Yes. After the great pressure of gas has been reduced there, the two will become equal.

Son. If the pressure of steam in a boiler was reduced to the same weight on the valve,—say if the two were alike equal to 15lbs., no steam then, I presume, father, would blow off, as it could not remove away that which was equal in power to itself.—Father: No; in that case there would be no blowing away of steam, as it could not (as you say) lift away that which was equal in power to itself.

Son: Then I presume no gas will accumulate in a mine after the pressure has become equal.—Father: I do not wish you to understand that no accumulation will take place; yet after the pressure has been so reduced very little will accumulate.

Son: I cannot see how any gas can make its way out when its pressure is reduced to the atmospheric pressure. It will not be able to press away the atmospheric weight to make its escape.—Father: To look at it that way it would appear no accumulation could take place. But you know the atmosphere, as before stated, is always changing. To-day its pressure may be 15lbs.; to-morrow, little more than 14lbs. Therefore, when its pressure is reduced from 15lbs. to 14lbs., the accumulation of gas takes place. The weight of the valve is stationary—not like air, elastic; the weight of the valve cannot press into the boiler, and like air work in and out, backward and forward, at every change.

Son: I see a little would accumulate, but the accumulation would only be until its pressure was reduced to the lowest atmospheric pressure.—Father: When gas is reduced in the strata to the lowest atmospheric pressure, say to near 14lbs., and the atmospheric weight returns to its former weight of 15lbs., the atmosphere itself is pressed into the strata to fill up the space of that gas which escaped when the weight of the atmosphere was reduced.

The Cause, or Why it is that some Mines Generate and Produce a Mixture of Carbonic Acid Gas (Black-Damp), and Explosive Gas.

Son: Do all mines accumulate alike explosive gas?—Father: No. One accumulates carbonic acid gas, which miners often call black-damp; another, explosive gas, which miners call fire-damp. But other mines accumulate a mixture of the two gases.

Son: You say all mines do not alike accumulate explosive gas. One accumulates explosive gas, another a mixture of gases, and others carbonic acid gas, or black-damp. I wish to know if all mines make explosive gas alike in quantity—that is, those which give off explosive gas?—Father: No; one gives off a great quantity, another not so much, and a third very little.

Son: You said just now, father, that the weight of the valve is not elastic, like air. What am I to understand by the air being elastic?—Father: As air is elastic, it is capable of being pressed into the strata to occupy the same space in the strata as the gas which is pressed or rushed out.

Son: Is air pressed into the strata, then, to balance the atmospheric weight after the pressure of gas therein is reduced below it?—Father: Yes. The air works in and out of the strata and mixes with the gas therein, as the two are elastic, and the same pressure which presses gas out will also press air in. Also, the atmospheric pressure is never long at a standstill, but works backwards and forwards, against and into the strata like a man breathing in and letting out air, backwards and forwards.

Son: Do you wish me to understand, then, by this that the strata afterwards gives off a mixture of air and explosive gas?—Father: I wish you to understand that when gas is so reduced the strata give off a mixture of explosive gas and black-damp.

Son: Is the confined air, then, which was pressed into the strata converted into black-damp?—Father: I believe such is the case. You know a man, by breathing, lets air into his body, and that air, when let out, is converted into carbon; so, in like manner, the confined air is afterwards converted into carbonic acid gas, or black-damp.

Son: Then mines like this accumulate a mixture of explosive gas and black-damp?—Father: Yes. They accumulate the two gases until all the explosive gas is exhausted, after which the mine accumulates black-damp only.

Son: Is it not surprising? I see very clearly, now, how one mine accumulates explosive gas, another a mixture of gases, and a third black-damp, or carbonic acid gas. But have you seen air pressed into the strata the way you show?—Father: I have seen air enter into open spaces in coal, stone, and rock, which drew in a candle-flame, and the next day the same open space which drew in air gave off a mixture of gases, and, by observing them I found the open spaces alternately gave off and let in air as the weather changed.

Son: Have you seen any other thing to convince you the air passed in and out of the strata?—Father: Yes; a number of men under my charge were working one day near to the workings of an old colliery. They holed into the old workings. When they had got a hole through, air passed through the hole into the old workings like air rushing to an up-cast near at hand. This enabled me and others to travel a great distance on the tramroads belonging to the old workings. The men with me were at a loss to know why air entered through the hole into the old workings; but, as I knew it was only a return of the weight or pressure of the atmosphere, I told them not to be surprised if to-morrow black-damp rushed out of the hole from the old workings.

Son: And was that the case?—Father: Yes. One day we were able to travel into the old tram-roads a great distance; another day we were not able to get to the hole from whence damp came out. It was like a weather-glass for the men.

How or Why a Change in the Weather Affects the Workings of a Mine with Gases.

Son: Why are mines affected by a change of the weather? —Father: Because the weight of the atmosphere which presses gas in the strata is diminished. When a change in the weather takes place the weight of the atmosphere is diminished from 15lbs. to near 14lbs. This diminishing weight of the atmosphere causes an extra discharge of gas, as an extra discharge of steam would blow out of a boiler if a little weight was taken off the valve. The moment the pressure of the atmosphere is reduced, gas expands from every place into which it is compressed.

Son: Do not miners often say, on seeing a cloudy wet morning, they will not be able to work that day? and also say so when the wind blows in a certain direction?—Father; Yes; the miner knows the weather affects his working place, but he has not the knowledge to know how the weather affects his place.

Son: Are all working places so affected as not to allow the men to work when a change of weather takes place?—Father: All are more or less affected, but all are not so much as to prevent men from working in them.

Son: Why are not all affected alike?—Father: Because some mines have very little air for ventilating purposes—only just sufficient to take away the gases on those days when little accumulates. Therefore, when a change of the weather takes place, the air is not sufficient for the extra quantity of gas generated.

Son: I see much caution and care is required to prevent explosions. Is there any forerunner to give notice to the men of a change in the weather, so as to have a knowledge of the extra accumulation of gases?—Father: The barometer will show when a change takes place, but will not show before the extra accumulation of gas commences. The change in the two is seen at one and the same time. Therefore, there is nothing to give notice beforehand.

Son: I think, father, I have a good knowledge, now, how mines accumulate gases. I shall be glad to know how mines are ventilated, and also to know the best way of ventilation to prevent loss of life; as there is often great loss of life by explosions, and great loss of life caused by not ventilating properly?—Father: I will give you a knowledge of several ways of ventilating mines before I have done, as well as a knowledge of the best way, and what I say I know no one can contradict.

The cause why Air is Propelled down, through, and around the Workings of a Mine.

Son: Are not mines ventilated by a large furnace at the bottom of the upcast shaft?—Father: Yes; but there is the steam-jet, the bellows, and the fan employed also for ventilating mines.

Son: Well, but they do not, I presume, draw or pull air like the furnace through the workings of a mine?—Father: Air is not drawn through the workings by the furnace.

Son: Miners often say that the larger the furnace, the more it will pull air through holes and places nearest the up-cast.—Father: I know miners often say and think so; they know no better.

Son: If air is neither drawn nor pulled, how is it caused to pass through the workings?—Father: Heat, you know, will make almost everything expand, and, as air is elastic, cold air expands very much by heat; therefore, the furnace produces ventilation by making air hot at the bottom of the upcast.

Son: Then, when air expands, does it become lighter in proportion to its bulk with the cold air?—Father: Yes. If one foot of cold air expands by heat into two feet, the two feet, you know, will only weigh the same weight as one foot.

Son: Then heat makes air so light, that it rushes like a balloon up the upcast and out of a mine?—Father: Yes. And, with the air rushing up one shaft, the great weight of air in the other is too great to remain in its place; therefore, it falls down or rushes forward to occupy the place of the hot air.

Son: I see; a furnace is like a pump emptying a shaft of water—as the water is pumped out it receives a fresh supply, which rushes in from the other shaft to occupy the place of that pumped out.—Father: Yes. If two shafts and the workings were full to the surface, with water, the yard of water nearest to the bottom would be pressed upon by the whole weight of water above it, and the water in the workings between the shafts would be pressed upon by the water from each shaft with an equal force. And it would remain stagnant, or motionless, unless an outlet was made for it, because the pressure of water in one shaft would be equal to that in the other. So in like manner will air press towards the up-cast as the pressure diminishes between the two.

Son: Air is not pulled, then, as miners often say, like something pulled or drawn with a rope, but is pressed into the upcast by the great weight of cold air in the downcast? But how does a steam-jet, a bellows, and a fan ventilate mines, as air is not made hot by them?

Father: Well, as you have asked me questions, all of which I have answered to the best of my ability, I will now ask you a few questions.—Son: I fear I shall not be able to answer your questions.

Father: The questions I require you to answer will be very simple.—Son: If so, I will try to answer them.

Father: By way of illustration, then, I will suppose you to have a pair of scales, with a 15lb. weight in one scale, and a 15lb. weight in the other: will the weight of one overbalance or weigh down the other weight?—Son: No. The scales would be at a standstill, because the weights would be equal in the two.

Father: Well, but if you add 1lb. more to one of them, making 16lbs. in one and 15lbs. in the other?—Son: That being the case the 16lbs. weight would be sure to weigh down the other.

Father: But suppose you take off 1lb., making 15lbs. in one and 14lbs. in the other?—Son: If so, the 15lbs. weight would weigh down the 14lbs. with the same speed as the 16lbs. weighed down the 15lbs.

Father: Very well. By this I wish you to understand that the atmosphere presses with a weight of 15lbs. into and upon the top of the up-cast as well as into and upon the top of the down-cast, and as two 15lbs. will not overbalance each other, but be at a standstill, so in like manner will air in mines be at a standstill with an atmospheric weight of 15lbs. pressing at the top of each shaft, unless the weight is diminished or increased at either the one or the other. That is to say, all that is required to cause air to pass down one shaft and up another, is either to add to or diminish the weight of the atmosphere at either the one or the other shaft.

Son: Will the steam-jet, bellows, and fan diminish or increase the atmospheric weight at the top of either shaft?—Father: It will send in a greater pressure, or force out the air at the top of the up-cast to diminish the pressure. Therefore, in proportion to its force it diminishes or increases the pressure of the air by which ventilation is produced.

Son: How wonderful, father, is ventilation, and yet so clear that if a blind man cannot see it he is as dark as midnight. But may a steam-jet or fan, &c., be fixed to work at the top of either shaft?—Father: They may; as the amount of air produced for the workings will be just the same, if fixed at one or at the other. You know a pound of pressure, added or diminished, is like the scales—one and the same. Yet the steam, no doubt, would affect the workings if the jet were fixed at the top of the down-cast.

Son: Suppose you had a ventilating fan, at which shaft would you fix it?—Father: If possible, I would fix it at the top of the downcast.

Son: But why; when the same quantity of air is produced at one as well as at the other shaft?—Father: I know the quantity of air for the workings would be the same, but there would be less danger of filling the workings with explosive gas.

Son: Filling the workings with explosive gas? Why, how can a ventilating fan fill the workings with gas?—Father: You know I have stated before, that gas is pressed or pent-up in the strata by the great weight of the atmosphere; therefore, anything that takes away the weight which presses the gas in would let the gas out, like letting out steam from a boiler, by taking off the weight off the valve. Now, in case a ventilating fan were fixed at the top of the up-cast to propel air out of a mine, if the air passage between the shafts suddenly closed up, every stroke of the fan would empty out that air which pressed in the gas, by which the mine would suddenly fill up with gas, and cause, no doubt, great loss of life.

Son: Do you think it would not fill, then, with gas, if fixed to force air into the down-cast?—Father: No; because every stroke of the fan would press a greater weight upon the pent-up gas, and give more time for the men to escape the danger.

Son: It requires, I see, much caution and care, and also a person with a good foresight, to prevent loss of life in mines. But I fully expected to have had, father, before this, a little conversation how gases are conducted by air through and around the workings in mines.—Father: It it my wish to impress on your mind, and also on every miner in the kingdom, things that will do good for years to come; therefore, as you have a knowledge how air is made to pass down into a mine, we will have a little conversation now how air is made to pass several ways in and through the workings of a mine.

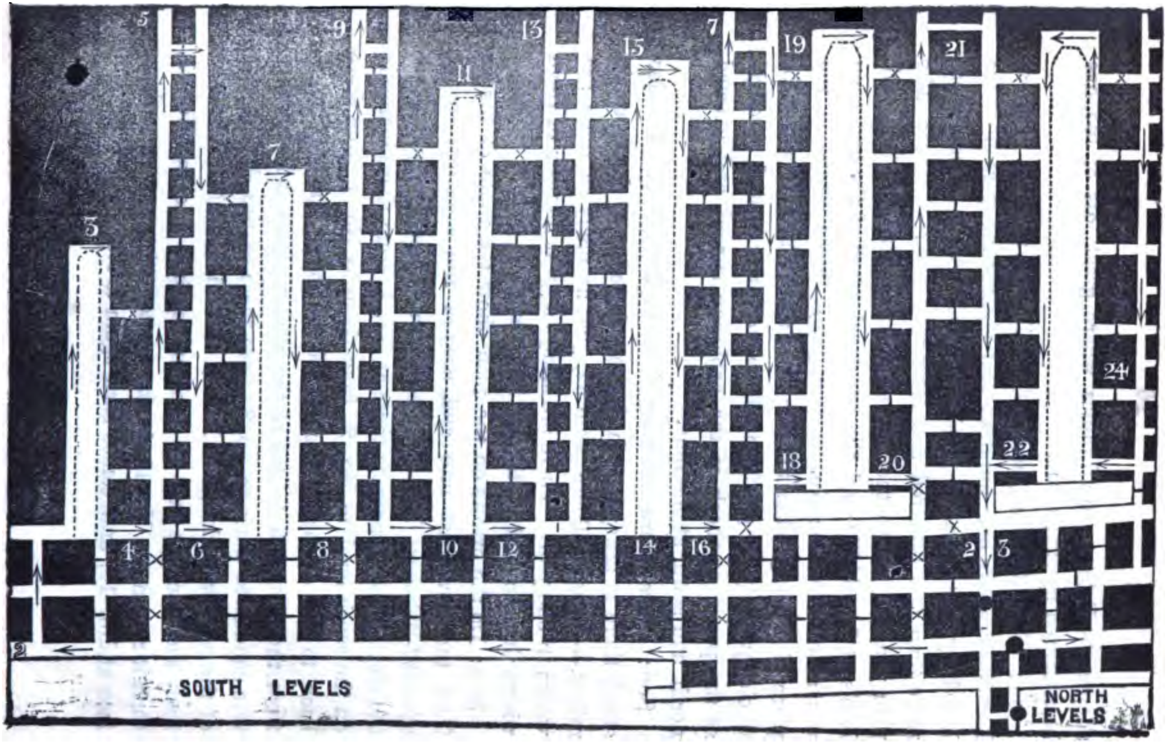
Son: Will you be able to show how air passed around Lund-hill workings, where 189 lives were lost, and at Risca, and at all those places where great numbers have been lost; and also show a better way to prevent loss of life?—Father: Yes; I shall be able to show the mode of ventilation at those places, and also a better way.

Son: Did you not show the mode of ventilation at Lund-hill which caused the four months' discussion in the public papers between you and the late John Wales, Esq., viewer in the north of England?—Father: Yes; poor Mr. Wales, I was sorry to hear of his death. The north people lost a valuable man when he died; he was a man with a good knowledge of mine ventilation. He did not charge me with not showing properly the mode of ventilation at Lund-hill, or the improved mode, but he had a notion I had made an error in the non-fixing of a regulator.

Several Modes or Ways of Ventilating Mines.

Son: You have a plan, I see, showing the mode of ventilating and working of mines. Where is this mode of ventilation

PLAN No. 1, of Ventilation at Lund-hill before the Explosion.



adopted?—Father: In all mines where great loss of life has been caused by explosions.

Son: Was this the mode of ventilation adopted then at Lund-hill, where one hundred and eighty-nine persons were killed by that dreadful explosion, and also at Risca, where more than one hundred and forty were lost?—Father: The plan you see shows the mode of ventilation on the south levels at Lund-hill; and the supposed place of the explosion was at or near the No. 24 (see plan); some supposed the place of the explosion to have been at the furnace, where the whole quantity of gas from all the workings passed through, as the power or shock of the explosion spread, and affected north and south at one time.

Son: Were there not many doors at Lund-hill? I understand there is always much danger where many doors are in mines.—Father: There were 52, just as many as there are weeks in one year. There are always a great number of them where this mode of ventilation is adopted.

Son: Do the arrows on the plan show the route of the air from the down-cast into and around the workings to the up-cast?—Father: Yes. You see the arrows show the passage of the air; it commences its route at No. 1, from there it travels on the south level to No. 2, from there to No. 3, from there back to No. 4, then onward to No. 5, back again to No. 6, from there onward to one of the working faces at No. 7, then it is conducted back to No. 8, from there to the face of one of the narrow workings at No. 9, it then returns to No. 10, from there to the face of another working place at No. 11, then it returns to No. 12, it then enters the narrow working face at No. 13, and comes back again to No. 14, Son: Well, father, what a great route air travels by this mode of ventilation.—Father: Yes, and if the route extended as far, from the down-cast through the workings to the up-cast, as one end of the river Nile is far from the other, go it must if only it can travel. There is no alternative with some managers but one continuous route conducting explosive gases into every part of a mine.

Son: By passing air backwards and forwards into and out of the working places there must be a large quantity of gas collected in the air long before it discharges itself at the top of the up cast. The air has yet to travel in and out from No. 14 to Nos. 22 and 23.—Father: At No. 22 (see plan) the gases accumulated in the air from all the workings in the north part of the mine meet the adulterated air from the south; at that place the two currents join. Afterwards this large adulterated current passes through a blazing fire or furnace at No. 23.

Son: Is this mode of very ancient origin?—Father: It was first adopted by our great grandfathers in the early days of coal mining, and, I am sorry to say, handed down from one generation to another, as it exists at the present day.

Son: Is there no improvement to be made for the better and safer working of mines, and, if so, why keep to so great a life-destroyer?—Father: There are improvements in mine ventilating as well as in all other things, yet I cannot tell why the improvements are not adopted, unless managers wish not to give up what was left them by their ancestors; or, their knowledge of mine ventilation may only consist in what was well known in the early days of mining.

Son: If that mode of ventilation is adopted we may well have, and also expect, great loss of life and property. I fear many lives have been lost by it.—Father: Many lost! The number is too great to be told. Your father was left in the world fatherless by it, and, from early life, I have had to make my way through the world without the blessing of a parent's care.

Son: I think, father, there was not so great a number of lives lost by explosions in the early days of coal mining as at the present time by the same mode. Can you tell why there was not?—Father: Because they had only limited means of getting out coal to the surface, they had only a limited number of works, they had only a limited number of persons employed in the works, and only limited means of ventilating them. Therefore, if they had only a limited number of persons, of means, of works, and of air, they had not so much gas in the air at the time of an explosion; that is to say, they had less air, and they had less works for the air to pass around; therefore they had less explosive gas in the air when it ignited; and if less gas, the power of the explosion would be less when it did take place; and if the explosive power were less, and there was a less number of works, there would be a less number of persons lost at the time of an explosion. Therefore, by the same mode of ventilation there was not so great a number of persons lost as now.

The Danger of one Mode of Ventilation, and the Safety of another.

Son: Is not air conducted from one working part to another, clearing away the gas in its passage, from all places in its route?—Father: Some managers adopt that mode for the ventilation of mines, but it is neither safe nor profitable, for miner or master.]

Son; Why not safe and profitable?—Father: Because the mode requires many doors fixing in the tram-gates to impel air forward from one working to another, and to allow waggons to pass and repass with coal from the workings. It is unsafe, because, if one door be left open, all the lives would be jeopardised; unsafe, because, if one place be affected, all the miners are in danger; unsafe, because explosive gas, conducted from all parts of the mine, will make a large quantity when collected; and, therefore, the power of the explosion will be very great when it does take place; unsafe, because an explosion in any one part would affect the whole mine. There is expense, too, in making and keeping air-gates large enough to allow the passage of sufficient air to take the gases away from all the separate working-places; expense in making a great number of doors; expense in fixing them; expense in opening and closing them to allow waggons to pass and repass; expense in the furnace expenditure of coal, as a great friction of the air is caused by taking a large quantity into and around so many working-places; expense in destroying the whole workings if so large a quantity of gas become ignited; expense in day-wage work, &c., to make all good after; and expense in making coffins for the many men who have lost their lives from an explosion.

Son: If air be conducted, then, from one place to another it it is not safe?—Father: No; As may be seen by the mode of ventilation adopted at Lund-hill, all the gases generated from the strata in the whole mine are collected in the air, as it passes onward from place to place, until the accumulation of gas becomes so great that an awful explosion often takes place.

Son: I wish to see, father, a little clearer, as I do not understand it properly.—Father: Well, suppose five separate groups of miners are working where so much explosive gas accumulates that each place requires 6,000 feet of air per minute for ventilating purposes. Now, if all the five currents of air make one, and the 30,000 feet pass through all the workings in one continuous route, all the five parts will be affected by an explosion, because all the separate working parts accumulate gas in the draught in which the explosion takes place, and as all are ventilated by it, all are affected in the same manner. Among the first group of miners all the air enters, after which it leaves that group or place and passes on to the second group, from them to the third, from them it proceeds to the fourth, and lastly to the fifth group. In the first group the men are well ventilated, and may be considered safe, providing that air and gas be not allowed to pass over a burning fire or furnace. In the second group they are less safe, from the fact that all the fire-damp accumulated in the first group goes directly in a current upon the second group; then it proceeds to the third, from them it passes on, with the gases accumulated in its passage, to the fourth group; and then onward the adulterated current goes to the fifth group. Who, indeed, does not see that the miners in the fourth and fifth positions are liable at any moment to be destroyed by an explosion of fire-damp, unless the greatest caution be exercised? One part of the mine would be filled with raging flames, and the men scorched to death by the burning gases; in another they would be killed instantaneously by the expansion of the hot air and gas, or suffocated by the noxious gases which fill all parts of a mine after an explosion.

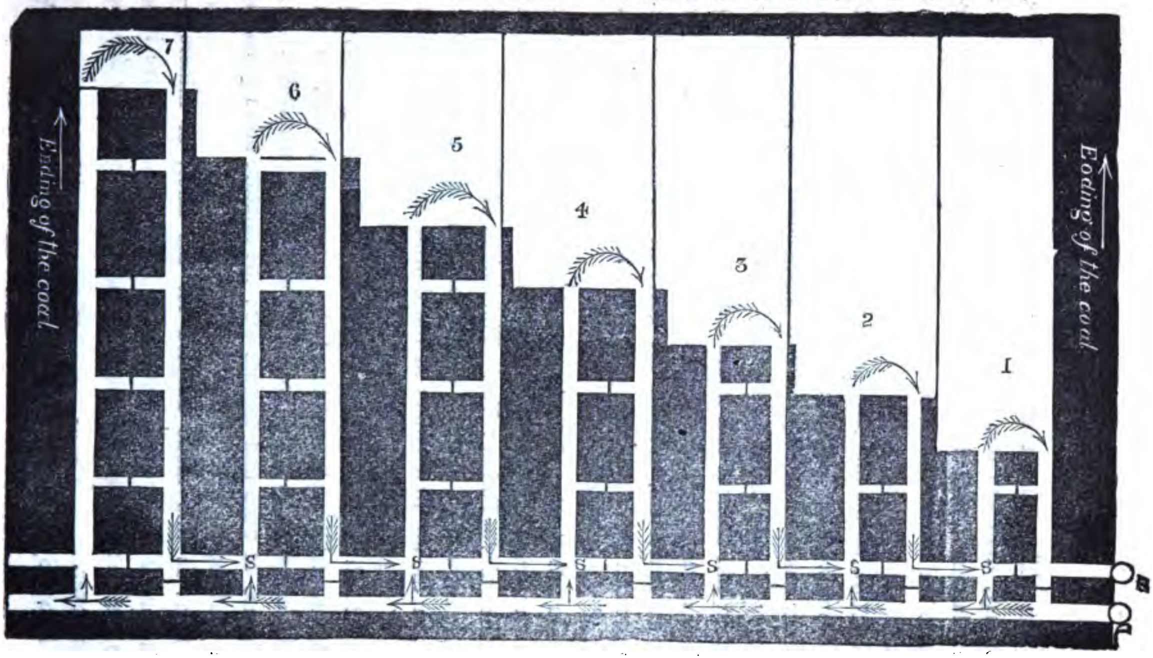
Son: There are other ways or modes of ventilating mines, you say, than the one adopted at Lund-hill? The mode of ventilation adopted there was that of conducting the *whole* current of air around in one passage.—Father: Yes, there are other ways of ventilation. The air is conducted by another mode in the following manner:—One portion of it is conducted pure into one working place; after ventilating the said place, and the air has become impure with gases collected, then a fresh supply of pure air is mixed with it to ventilate another place; and in like manner this mixture of pure and impure air takes place always when each working place is ventilated; and so the air passes on, with all the gases in the mine accumulated in it from every working part, until it discharges itself at the top of the up-cast.

Son: Will plan No. 2 show this mode of ventilation by which working-places are supplied with a mixture of pure and impure air?—Father: Yes. The points of the arrows on the plan show the passage of the air through the workings. When the air first enters at the down-cast, it passes direct to No. 7 working-place; after ventilating this place it is supplied with fresh air for the ventilation of No. 6 working-place, the mixture taking place at the letter S (see plan), and, in like manner, all the other working parts are ventilated with a mixture of pure and impure air; the mixture takes place for all parts at the letters S S.

Son: Is this mode adopted for the safety of miners?—Father: Those persons who adopt such a mode believe it to be for the good and safety of miners, and economy for the employer.

Son: By this mode, air-gates, I see, do not require to be as

PLAN No. 2—*The Impure Air supplied with Fresh Air.*



large as those where the whole quantity of wind passes in one current through the workings, like Lund-hill; therefore, the expenditure will no doubt be much less.—Father: The mode would be more economical than if the whole of the air passed around the workings in one current; but the danger of loss of life by an explosion would be the same as that of ventilating by one current.

Son: It is clear that an air-gate will not require to be so large, for, say 6,000 feet, or 12,000 feet of air to pass, as for 50,000 or 60,000 feet, and therefore, the expenditure will be much less. But why is the danger of loss of life the same?—Father: Because this mode of ventilation neither divides air nor gas, the gas being conducted in the same way as in the other method I described, from one working part to another, in one continuous route, so that all the gases in the mine become formed, or accumulated, into one large quantity; therefore an explosion in any part of the mine would ignite the whole quantity of gas, the power of such an explosion would affect all parts where the air passed, and cause great loss of life.

Son: The mode of ventilating mines by one continuous route is caused, you say, by fixing doors to propel air forward from one working part to another, I wish to know then how this mode of supplying the workings with a mixture of pure and impure air is accomplished?—Father; It is accomplished by fixing *regulating* doors in the air-passage. Air, you know, will always rush by the nearest route from the down-cast to the up-cast, and regulating doors are fixed in the air-passages to stop the great rush of air, and propel a portion of it into, and around, the longest routes, which would otherwise be left without air. The doors are fixed in the openings *between* the in-take and return air passages, at or near the letters S S.

Son: I shall be glad to know, at a future day, why air rushes around the nearest workings, and the longer route of workings are left destitute of air; but how, father, are regulating doors fixed in mines?—Father: They are fixed in those air-passages through which the air rushes with great velocity, to take off, or propel such quantities of air as are required for other workings, and are so fixed as not to fill the whole space of the air-passage, but open spaces are left to allow a proper quantity of air to supply other working parts of the mine.

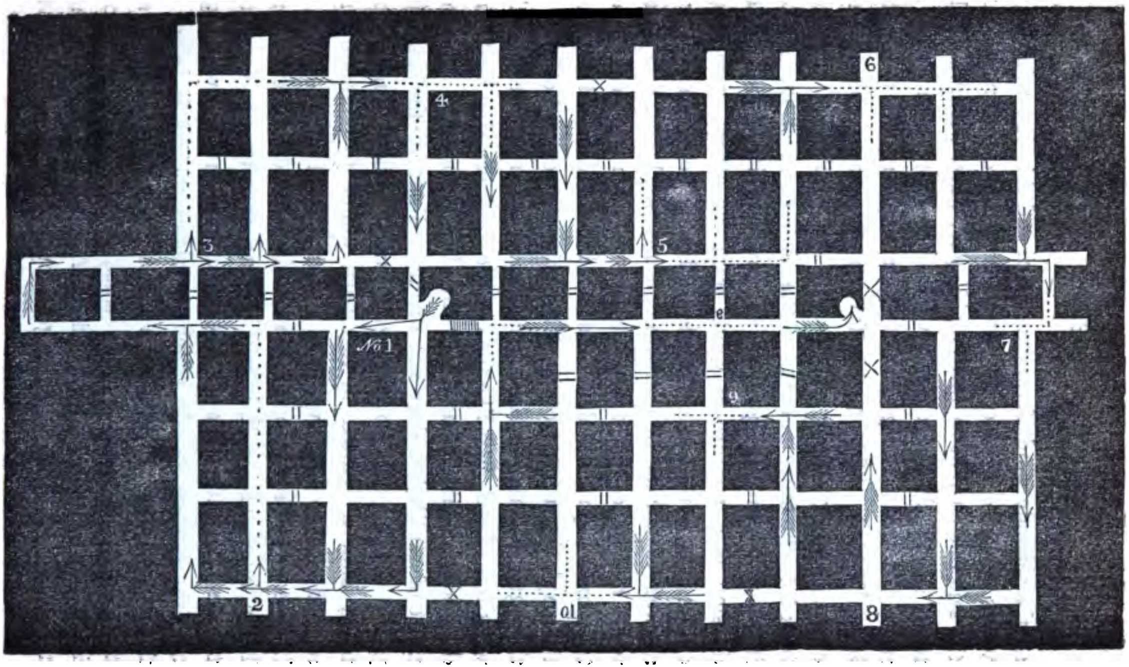
Son: Very good, father; but what other modes of ventilation are adopted?—Father: Another is, that of conducting the air into the workings after the plan of ventilation adopted by the late John Buddle, Esq., viewer in the North of England.

The Power of an Explosion.

Son: Was Mr. Buddle's plan considered to be a safe mode of ventilation?—Father: I believe it was much thought of in his day; yet it is not a safe mode of ventilation.

Son: What was the mode he adopted?—Father: It was one similar to several modes of ventilation I have seen adopted in mines at this day, and which many managers call dividing the air; yet, it is not what may be called splitting the air. This mode of ventilation is to divide the air into separate parts, for separate groups of miners; after which all those separate parts of air return into the same current again from which they separated. Then again, this one current of a mixture of winds is divided a second time for more groups of miners; after this all the separate winds form one again, and this one mixture of winds passes on further into the extremity of the mine until the said one current requires dividing for other workings of the mine, and so the same is allowed to divide or separate into as many parts as workings, returning and forming one wind after being divided. This mode of ventilation cannot be properly called splitting the air, because the air is allowed to return back into the other portions of the air from which it separated itself, and no working part has a separate distinct wind, as each division is a mixture of winds from the others, with gases collected from the same in each wind. Therefore, as the air is allowed to spread in and through the workings, every part would be affected by an explosion therein; for the gases collected from all parts would be mixed in the said wind in which the explosion might occur. This being the case, the flame of the ignited gas would fly and spread in and through the workings of each part like the electric fluid, carrying death and destruction in its passage. By this it will be seen that this mode of ventilation does not divide or diminish the explosive power (gas), as the explosive gas would be like a combustible train, and, if ignited in any part, would fly through and around all the parts where it circulated. Plan No. 3 is, I believe, a representation of Mr. Buddle's mode of ventilation; by an inspection of it, it will be seen that the air separates ten times in its passage through and around the workings, and the current of air which ventilates the whole mine, is formed into one wind as often as it is divided; by which, all the gas generating from every strata, through the whole mine, is collected into one vast quantity. As to the number of times the air is separated in its passage through, from the down-cast to

PLAN No. 3.



the up-cast, see Plan at No. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10. This mode of ventilation, if called a splitting of the air, is not a separate distinct dividing of the gas.

Son: Was this the mode of ventilation you alluded to in your reply to a person in the "Miner," who requested you to inform him the meaning of split winds in mines?—Father: This plan does not show the mode of splitting air, yet it is the one I alluded to in my letter.

Son: Let me see the letter.—Father: Here it is; it will give you a knowledge between this mode and that of ventilating by separate distinct currents.

THE LETTER.

SIR,—In your "Notices to Correspondents" of last week's impression (January 2), I am requested to inform a "Constant Reader" the meaning of "splitting" the air.

My object through life has always been (and I hope will, until my work on earth is finished) to try to better, if possible, my fellow-workman—the miner. When I speak of mine ventilation, it is from a practical knowledge of seeing and doing the work, and not from a knowledge only of theory, reading, and hearing. When I speak of air splitting, I mean separate, distinct currents, and not that kind of splitting which is similar to that which takes place when the wind blows on the surface against a building, the wind being separated by it, and afterwards mixed again; and so the wind is divided and mixed in passing and repassing every building. The above is similar, I say, to the splitting adopted by some managers. They allow the whole of the air to pass in one large current until one portion of the air is propelled by the great friction of the air around one part of the mine, and another portion around another part; and so the said air is allowed to split or divide as it rushes through the mine into as many parts as are working, returning and forming one wind after it has been divided; therefore, it is not a separate, distinct current or wind, but a mixture of winds, with gases collected in the wind from all parts. This mode, as before stated, divides neither air nor gas, as gases from all parts are mixed in the one said current; therefore an explosion by the same would affect all. But, I am asked, what is meant by splitting of the air? I would also ask, what amount of air can be produced for the whole workings of a mine? Can 20,000 feet, 40,000 feet, 60,000 feet, 80,000 feet, or 100,000 feet be produced per minute? Be that amount less or more, do not propel in one current the whole of it around the workings of a mine. Divide, split, or separate the whole into "distinct currents" or parts, of say from 5,000 to 7,000 feet of air for each current; after which, if five, ten, fifteen, or twenty miners are getting coal in one district of the mine, supply the said number of miners with one current, say 6,000 feet of pure air direct from the down-cast; after which, conduct the said current direct from the said miners to the up-cast, and do not ventilate other workings with it afterwards. Supply another current, say 6,000 feet, of pure air to miners working in another part of the mine, conducting the said current as before direct from the down-cast to the working parts, and therefrom to the up-cast; and so on in a similar manner supply each party of miners with distinct currents.

If the accumulation of explosive gas be too great in the workings for, say 6,000 cubic feet of air, to dilute and render it harmless, reduce the number of workings for the said amount of air, or make two divisions of the said number of works, so that the gas may be divided and rendered harmless by each separate current or division of air—that is, regulate or reduce the number of works to be ventilated with that air in proportion to the quantity of gas accumulating in such works. But it may be asked how or by what way is 5,000 or 7,000 feet of air to be sent or propelled into the workings in separate quantities, as the distances for the air to travel are not alike equal in length, the distance being much greater around one number of miners than around another; and such being the case, more than 6,000 feet of air may pass into and around one working part, and much less than the said amount around another part; by this one part will have a superabundance, and another a deficiency of air. In reply to the above—"Such, doubtless, will be the case if the air-gates be large enough to allow a larger portion of the air to pass into one part than into another." All that is needful in this case is simply to enter the return air-gates of those parts from which a little air is required to be taken, and, by fixing a regulator therein, each division of air may be so regulated as to allow only a sufficient quantity for each working part. Also, the impure air, in its return, may come in contact with the intake pure air of another division; if so, an overthrow, similar to a bridge over a canal, will be required at such part or place, the overthrow so constructed as not to allow a mixture of the two currents. Ventilate the working of a mine as above stated, and you will have separate or split winds therein, and no explosions like Risca, Lund-hill, and many more such like.

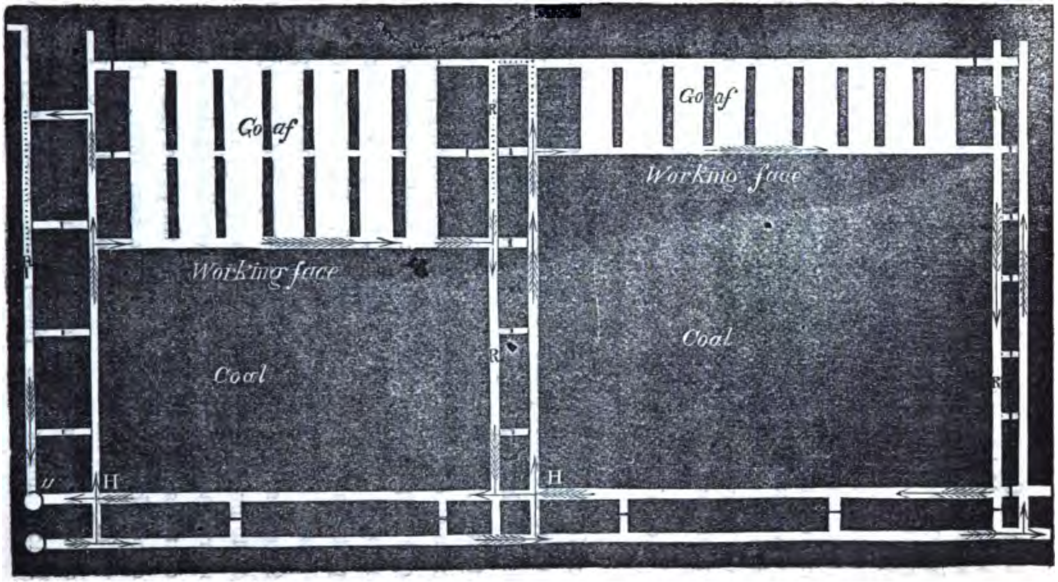
Yours faithfully,

St. Helen's, Jan. 11. WM. HOPTON.

Plan No. 4, is a representation of this mode of splitting the air, yet there are more plans which show this mode of ventilation.

Son: Then an explosion, I understand, by this mode of ventilation, would cause great loss of life; because all the gases accumulated in the air pass from one working place to another in one large quantity?—Father: Such is certainly the case. The object of ventilation, namely, the preservation of life and property, is altogether lost sight of. The mode of ventilation has always been to send around the workings a large current of air to take a large quantity of gas away; but the object of ventilation to prevent loss of life and property, should be to divide this large accumulation of gas by ventilating the working where it accumulates separately. Divide the power (gas), and the effect produced by an explosion will be very little. If you had to work in a room where a ton or barrel of gunpowder was exposed to a great number of people, and at any moment an explosion might take place, you would say, remove the

PLAN No. 4.



gunpowder, or divide it into pounds, so that the effect may not be very great if a part should become ignited.

Son: I see the cause, father, now, of people often saying after an explosion of fire-damp, that such and such mine was (where great loss of life has been caused) well ventilated; it was well ventilated with impure air.—Father: No mine ventilated with impure air can be called a well-ventilated one, if the air which passes through be ever so great. I do not doubt for a moment but, where great loss of life and property has been caused, they have had much air; but it was impure. No one will doubt that, for the explosion which caused the loss is the witness, as an explosion cannot take place in pure air where there is no gas.

How the Power of an Explosion may be Diminished.

Son: The best mode of ventilating mines, then, for the safety of miners, is that of splitting the air into parts, by which each group of miners is supplied separately with their own pure air direct from the down-cast?—Father: Yes; pure air is split to allow each working part its own proportionate quantity, in proportion to the accumulation of gases in each part.

Son: I see, father, several letters on the plan R and H, what am I to understand by them?—Father: An overthrow is fixed in those places where you see an H, and a regulator at R. A crossing is so fixed as to prevent a mixture of pure and impure air, and is so constructed that one can cross over the other. Regulators are also fixed to supply each separate working-place with a due quantity of air, which is in proportion to the accumulation of gas; if no regulators were fixed, one part would receive, in proportion to the distances, more air than another.

Son: Then explosive gas by this mode is prevented from accumulating in large quantities?—Father: Yes; the object of splitting is to accomplish it. If one wind pass around, say, four working parts, explosive gas will accumulate in the air, from all the parts, so that four times more gas will be in the current of air than there would be if only one-fourth of the air ventilated one part or place only. Therefore, in proportion to the quantity of gas, so is the power of an explosion.

Son: Then what you wish me and others to understand is this; if, say, one thousand feet of gas accumulated per minute in each working part, you would not ventilate, say, four parts with one great current of air, as by so doing you would have four thousand feet of gas in it, but you would ventilate each part separately, because, by so ventilating, you have only one thousand feet of gas to explode, and not an explosion of four thousand feet; therefore, by reducing the gas to one-fourth, the explosive power is reduced fourfold.—Father: Such would certainly be the case. If loss of life and property must be prevented, splitting of the air for the ventilation of mines must be adopted, because great loss of life is caused by igniting too large a quantity of gas. Split the air for workings into parts, and you divide or split the great explosive power (gas) with the air—that is to say, take the gas away, and you take that power away which causes such loss of life.

Son: Then if the workings of four groups of miners are ventilated separately, and if gas ignites in one, you prevent the explosion spreading to the accumulation of gas in the other three groups, and therefore prevent loss of life, and you also reduce the explosive power in any part where gas explodes by three-fourths.—Father: To ventilate a mine by splitting the air, several objects are accomplished, by which loss of life and property is prevented. 1.—The explosive power is reduced to one-fourth less than it would be if one large current of air ventilated all the four parts; and by the power being so reduced, the men may escape from the exploded part without loss of life. 2.—As the explosion is confined to the one particular part where the gas ignites, you prevent loss of life in the other three parts, because no explosion takes place in them, as the route of the explosive power can only spread around one part, and not around all the four. 3.—The quantity of choke-damp produced by an explosion is reduced by this mode of ventilation to one-fourth. You know in proportion to the quantity of explosive gas ignited, so is the quantity of choke-damp after an explosion; therefore when the quantity of choke-damp (which destroys the life of the miner) is diminished, we must expect the loss of life to be diminished accordingly. 4.—The danger to a person's life is reduced fourfold, because those employed in other parts do not jeopardise their lives by working in the gas, which has passed around other places. 5.—This mode prevents doors being blown away, because few are required, and the power which destroys them is reduced, therefore, the danger of loss of life by the same is reduced. 6.—This mode supplies every working part direct from the down-cast with pure air; therefore, when an explosion takes place, the fresh air enters the exploded part shortly after, and loss of life is often prevented. But such is not the case by the other mode of ventilation; lives are lost for the want of fresh air.

Son: Is there anything said, father, against this mode of ventilation?—Father: Yes, much is said against it, and that, too, by men professing to have an extensive knowledge of mining.

Son: What is said?—Father: It is said, if one wind does not ventilate—say four working parts—you take the air from the fourth part by ventilating each part separately, and, by so doing, you may have not a sufficiency of air for each part.

Son: Well, but they should also remember that if the three divisions of air do not pass around the fourth working-place, the gases accumulated in the said three divisions, also do not pass into the fourth working part, and therefore, if you take air from the said part, you also take gas from it. And there is more danger in not having a sufficiency of air to take a large quantity of gas from a great number of works, than not having a sufficiency of air for a less quantity of gas. There was sent through the workings at Lund-hill a large quantity of air to take a great quantity of gas from many parts, but the large current was not sufficient for the quantity of gas, and awful was the result. At Burradon, Risca, Cymmer, &c., a large current was also sent through the mine to take a large quantity of gas from many parts; but the current of air was not sufficient, and the result was accordingly. If gases accumulating in the workings of one group of miners cannot be rendered harmless by a certain quantity of air, gases accumulating in the workings of four groups of miners will not be rendered harmless by four times that amount of air. Therefore, as no one can show great loss of life by splitting, it is better to adopt that mode for the safety of miners.—Father: I think you will be able to show the public shortly the best mode of ventilation. Yet others recommend for the safety of miners stoppings, doors, and overthrows to be strong enough to withstand the shock or power of an explosion, because stoppings several feet thick are blown away by the power.

Son: It is very strange, father, for those professing to have much knowledge of mining, to talk in such a way. Divide, reduce, or diminish that power which blows the stoppings away, and you prevent miners from being blown away. It is of no use making stoppings, &c., to withstand a greater shock, if a miner's body is not able to withstand it. If such people were in a mine when an explosion takes place (if spared to get out), they would say—"Unless this power be reduced, I will not be found here again." But, father, how is this mode of splitting the air and gas, by which every working part of a mine may be supplied direct from the down-cast with pure air, accomplished?—Father: This mode is accomplished by fixing regulators and overthrows in a mine. Overthrows are similar to a bridge over a canal, over which passengers go at one end, and vessels pass through at the other. As the air passes pure from the down-cast into the workings of one division of miners, it may come in contact with the return impure air of another division; and, as the impure air is required to cross, or go over the pure, an overthrow is required at such place, to cause one division of air to cross the other—such crossings are so constructed as to prevent a mixture of the two. Regulators are also fixed in the nearest return air-gates to the up-cast shaft, to regulate the proper quantity of pure air in proportion to the gases accumulating in each part, by which one group of miners with a deficiency of air will be supplied with a sufficient quantity, or will take a little from those parts which have a superabundance.

Son: You say the mode of ventilating mines by splitting the air into separate distinct currents, is much better both for the safety of miners, and economy for employers. I shall be glad to know, father, why it is not adopted; is it because people think mines will accumulate more gas by this mode of ventilation?—Father: No; a change in the mode of ventilation, you know, will not cause an extra quantity of gas to accumulate in mines, as the accumulation is the same for one mode as for another.

Son: Yet people with no proper knowledge of mine ventilation may think there is less space or room in the air-passage, by the mode of splitting into distinct currents, than there would be if all the divisions of winds formed one wind, to pass in one current the whole quantity through such air-gates; and this is their objection. Father: If many divisions of air form one large current, and pass in one continuous route through one air-gate, space will be required in the passage accordingly; or the same quantity of air cannot be produced by one mode of ventilation as by the other; therefore, as there is more room for the air (in the passages) for separate divisions than for many, it cannot be the cause why such is not adopted.

Son: Will the explosive power be greater, and cause this mode not to be adopted?—Father: No; because dividing the air into separate distinct currents is reducing the gas, and reducing the gas is reducing that which produces the power of an explosion.

Son: Is the production of pure air for the workings much less by this mode of ventilation, and is that the cause why it is not adopted?—Father: No; because this mode will produce a much larger quantity of air, yet air will not be forced to pass through the workings in one large current, but be distributed in quantities in proportion to the accumulation of gas in each working part; and there will not be, as before, a large mixture of impure air. Therefore, this larger quantity of pure air produced is caused by diminishing the friction, by allowing a larger space in the air-passage.

Son: Some may have a notion, father, that if one large current of air ventilates, say six divisions of miners, one-sixth part of that current of air cannot ventilate or do one-sixth part of the work, as well as all the air does all the work?—Father: That cannot be the objection, because one-sixth part of the air will do one-sixth part of the work much better; for the impure air by this mode is conducted away to the up-cast, and not mixed with the pure air, to occupy its space in the air-passage, and impede its progress through the workings by taking up the space it ought to have.

Son: If one large current of air ventilates, say six divisions of miners, and this large current is, after ventilating the workings, very impure with gases, do you think that is the cause why splitting of air is not adopted?—Father: No, that cannot be the cause; as the quantity of gases conducted in and around the workings is much less by this mode than by others. Nearly one-half of the gas of the mine, by this mode of ventilation, does not enter the workings, but is conducted away to the up-cast. By the old mode of ventilation, the accumulation of gases in the returns of one part pass into the workings of another part; but not so by the new mode. If a mine cannot be worked with safety by the new mode of splitting, it cannot be worked with safety by ventilating many divisions of miners by one large current; because, if there is only one-sixth part of the air in a division, you have only one-sixth part of the workings to ventilate with that air, and the gas accumulating in the returns, as before stated, is conducted away from, and not into, the workings.

Son: Is it not adopted because the distance is not the same for air to travel by this mode as the other?—Father: No, that cannot be the cause, as air will travel a short distance much better than a long one. To split the air into parts and ventilate each working part separately, one division of air will only have to travel around one part, and not around six; therefore, air will travel around one much better than around six, as a person will travel one mile with a load much better than six.

Son: Is it not adopted because there is not the same need for the furnace to produce ventilation by one mode as the other?—Father: I cannot see that reducing the work of the furnace, will be any inducement for not adopting the mode, but a very strong one why it should be adopted; because, if air has only to travel around one part, and not around six, and also one division of air occupies the same space in the air-passage as six, the friction of that air will be very much diminished; and if the friction is much reduced, the furnace will produce for the workings a much larger quantity of air, because the quantity of air produced by a furnace is always in proportion to the friction overcome by it. Diminish the friction, and the furnace will (in proportion to it) produce you a larger quantity of air.

Son: Is this mode not adopted because falls of the roof may affect the air-passage, and not so by the other mode?—Father: There is more danger of falls affecting air-gates, by ventilating many workings with one large current, than by ventilating each separately, because, if there is not room for one division through the fall, there cannot be room for six, and if not room for one division, what would become of the men if all the six divisions of air forming one wind, were required to pass through the obstructed part?

Son: Is it because this mode of ventilating mines cannot be adopted where any other plan of working out coal is used?—Father: No, that cannot be the objection, because in the working of mines, there are always two or more gate-ways for every working part, as they cannot pass air both in and out with one. One gate-way is for air to enter, and the other to return; therefore, in its return you conduct the air direct to the up-cast, and not pass it around other workings. You ventilate all other parts in the same way.

Son: Do you think this mode is not adopted because the number of workings is thought to be too many for the air to ventilate, if split into parts?—Father: If one wind in one continued route will ventilate any number of works, the same wind will ventilate the same if split into divisions, because, nearly one-half of the gas is conducted from and not into the workings. By it the explosive power (gas) is reduced. The extent to which the explosion will spread is reduced, and the quantity of choke-damp is also reduced.

Son: Do you think they object to the mode because too expensive?—Father: It is not as expensive as the other modes, because there are fewer doors to make, to fix, to open and close when fixed; there is less expense in trappers (door-boys), less expense to make an air-gate for one division than for six, and less expense in coal for the furnace, as the friction of the air is reduced.

Son: Well, father, I am not able to ask any more questions why the mode of ventilating mines by separate distinct currents of air is not adopted. You clearly show there is no cause why great loss of life should take place in mines, as the mode is both better for the safety of the miner and for the economy of the employer. Where a great number of works, accumulating a large quantity of gas, is ventilated with a large quantity of air, I cannot see how, if a great loss of life is caused, the result can well be called accidental; because, how can anything be called accidental which is well known and seen before it takes place? They know if the mode is adopted it will cause great loss of life; yet it is adopted. Then, I ask, how can the loss be accidental?—Father: There is no reason for such loss of life, and I fear no contradiction in so stating; it is time to stop all such life-destroying modes. We have too many of those well-ventilated mines exploding, and too many lives lost by (it is said) tobacco-smoking, or gas becoming ignited from a flint-stone.

Son: I presume, father, if an explosion took place, you would not spend two or three days inquiring at what part of the mine the gas ignited, the extent to which the explosion had spread, the powerful effect produced by it; whether it was ignited by a candle-blaze, a safety lamp, a match, a tobacco-pipe, or a spark from a flint-stone; who ignited it, or by what means it became ignited; but how it was that such a quantity was allowed to accumulate, and what means of ventilation had been adopted to prevent its accumulation?—Father: I think it would be much better to inquire how it was that such a quantity of gas was there, for had it not been there no one could have ignited it. Remove the cause, and the effect will cease.

Son: You say, father, the mode of ventilating by separate distinct currents may be adopted where any plan of working out coal is used. As you have been an underground manager many years, I wish to know, if in those mines under your charge, you have always adopted the mode of separate distinct currents of air, that is, changed from the old to the new mode of ventilation?—Father: I have had charge of several mines in Yorkshire and Lancashire, and in those mines accumulating much explosive gas, I have always changed from the old mode to that of separate distinct currents, and by so doing prevented, I believe, much loss of life and property.

Son: You have had no loss of life by explosions,* you say, in the mines under your charge; but you may have had little or no explosive gas in such mines, and that may be the cause why you have had no loss of life.—Father: Like others, I have had mines varying in the quantity and quality of the accumulation of gases, yet few have had, I think, more explosive gas to contend with. I have seen men affected and struck by it in a moment's time, and seen it ignite and crack often in the safety-lamp. But my method of ventilation to prevent loss of life and property has always been—1.—To obtain all the air possible for the workings. 2.—Not to have more works to ventilate than pure air can reach. 3.—To ventilate those workings accumulating much explosive gas separately. 4.—To conduct explosive gas away from the miner and not to him, because there is a right and a wrong way of conducting air and gases through the workings of a mine. To illustrate my meaning, suppose a number of chemical works were near a large population, who become affected by breathing impure air at such time as the wind blows from the works towards them. But in case a change in the wind takes place, by which the noxious gases are blown away in an opposite direction; if the force or velocity of the winds be not one-twelfth of that which blew the gases to them, they will by this change of the wind breathe a purer atmosphere, as no gas can come against the wind, be its velocity ever so small. And so it is in ventilation of mines, if air be properly conducted around them. Miners' lives are often jeopardised by managers conducting the whole of the gases into and upon the tram-roads and waggoners.

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*Since this work went to press one person has been lost by going into another person's working place, with a naked light, before it was examined. He died in 13 days after being burnt. The power of the explosion was not sufficient to extinguish naked lights 30 yards distance from the place of the explosion.

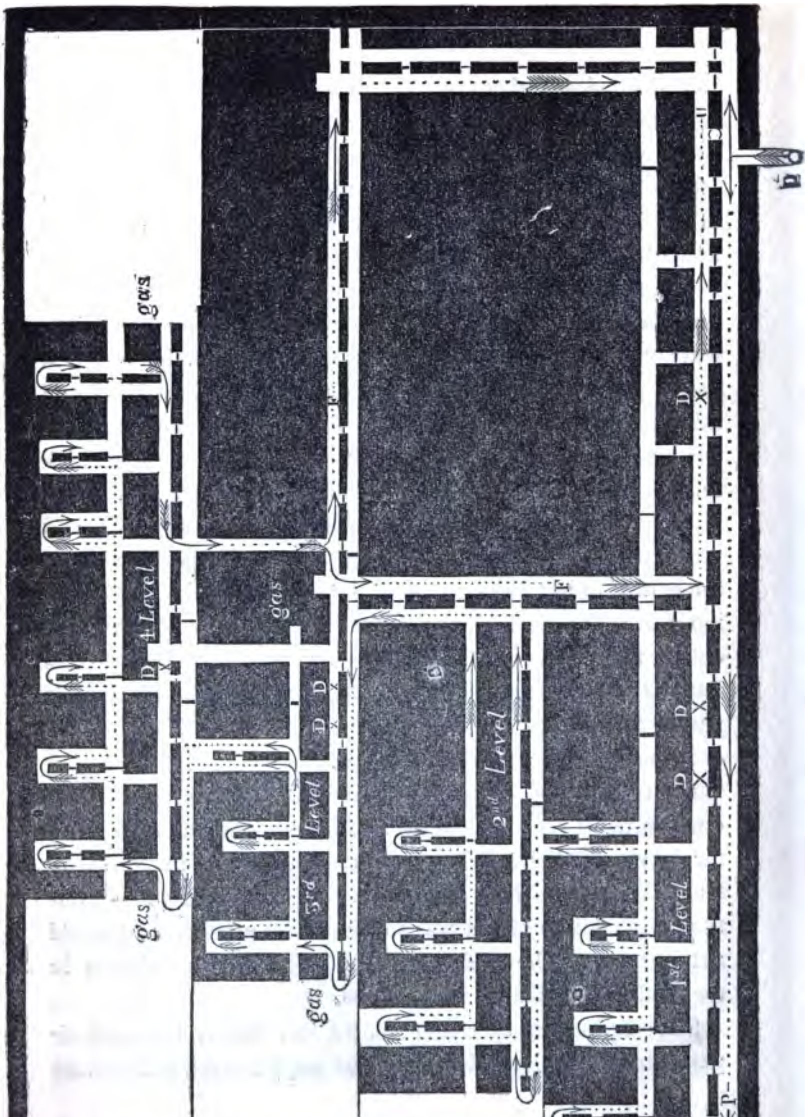
Son: When you were first engaged at a colliery, you adopted, I remember, separate distinct currents of air.—Father: Yes; I adopted the improved mode because I found in one mine much explosive gas accumulating. The men had to work with red-hot safety-lamps. The accumulation of gas was so great that coals were lost, as a safety-lamp could not burn, nor the place be approached; and in the waggon-roads, gas often ignited in the safety-lamps hundreds of yards from the working faces. As this state of things was so bad, I drew a plan to show my employer it was possible to make a change in the mode of ventilation, and adopt for the workings separate distinct currents of air; and having a good knowledge of mines and mining, he was at once convinced it would be much better for the safety of the men. He ordered its adoption, fearless of expense, but I assured him it would not be £3.

Son: I shall be glad, father, to see the way by which coal was worked out, the mine ventilated, and the improved mode you adopted.—Father: If you wish to change the mode of ventilation, it will not do at all times to change the mode of working out coal, in order to enable you to do so, as another mode of working may not answer for the seam of coal; therefore, in making a change in the mode of ventilation, you have often to contend with difficulties, because you cannot make air-gates in places you wish. I may also add, if a person has not got in him the ability to make a change in the mode of ventilation, without changing the mode of working out coal, he is not a proper person to take charge of the underground workings of a mine. In the mine in question, I had to make a change in the mode of ventilation, and not in the way of working, which may be seen in the two plans Nos. 5 and 6 before you. Plan No. 5 is a representation of how the mine was worked and ventilated when I first took charge. Plan 6 shows the same mode of working the coal, and the change I adopted in the mode of ventilation. You will see in plan No. 5 that the air enters the down-cast, and passes on the lower level to the letter P, a distance of nearly 800 yards, after which the air passes forward through and around all the workings in one continued route, and in one current.

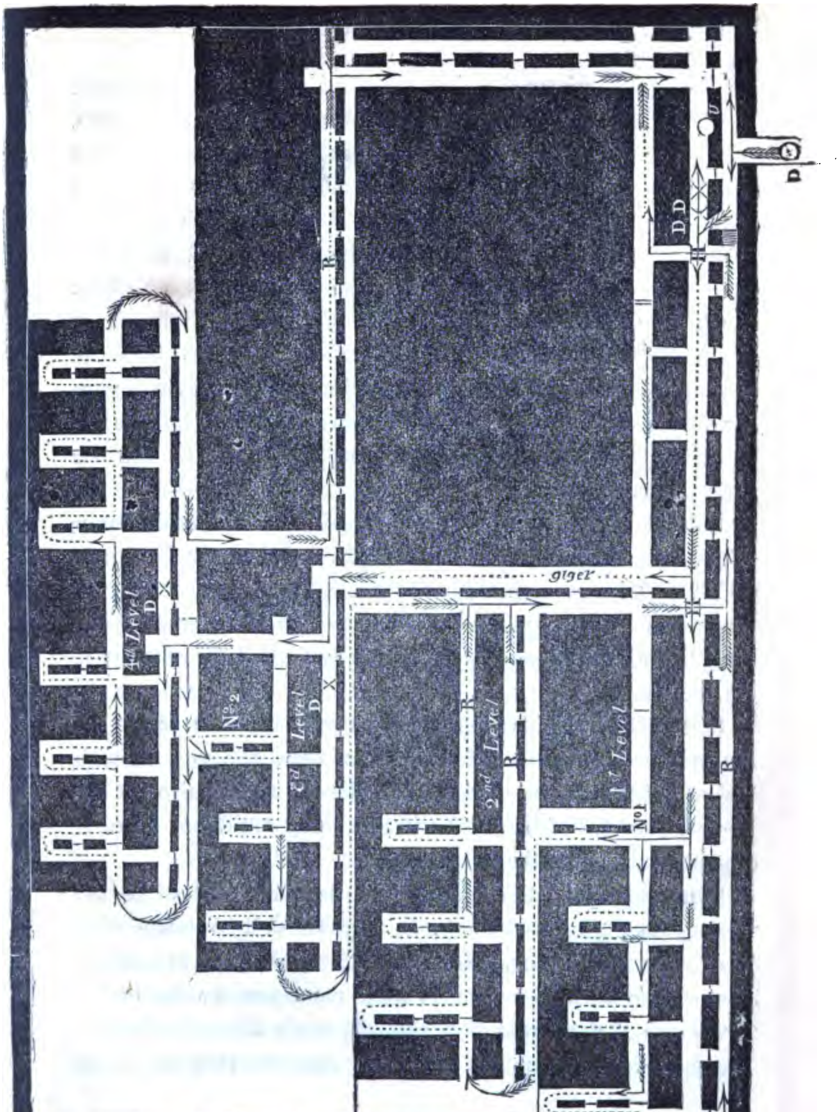
Son: Very good, father. But what am I to understand by the other letters I see on the plan?—Father: The letters D D are for doors. F F show where gas often exploded in the safety lamp. You see the third and fourth levels. Well, in those levels the accumulation of gas was so great that a safety lamp could not burn, and the coal had to be left until the change in the mode of ventilation was adopted.

Son: In looking over plan No. 6 I see, father, the pure air passes out of the lower level into the waggon road, and onward

PLAN No. 5.



PLAN No. 6.


D
DD
B
4th Level
D
X
No 2
2d Level
D
X
giger
2nd Level
R
B
1st Level
No 1
R

to the jigger, where the air divides for the third and fourth levels, by which one division takes place at No. 1, and at No. 2 another division of the air takes place, so that each level, I see, is ventilated separately, as fresh air enters from the down-cast to each level working. Therefore, each level will only have its own gas, and not the fourth level have gas conducted from the first, second, and third levels.—Father: Such is the case. By this mode of ventilation the gases accumulating in one working place do not pass into the workings of another; and you may blow into the workings pure air on the waggon roads without impure air, as the impure air is conducted from the workings on roads not in use for waggoners.

Son: I presume, father, an air-crossing is fixed at the letter H, and also a regulator at the letter R, and doors at the letters D D?—Father; You are right; such is the case. I only show the plans to give you a knowledge which of the two ways of ventilation is the best. By one way coal was left, but not so by the other.

Son: Did you clear the gases away, then, after your plan was adopted?—Father; Yes, the men were able to work with naked lights after, in nearly all the places; and we also got out the coal which had been left where a lamp could not burn, or be got near, before the change.

Son: No doubt the men would be very glad when the change took place.—Father: It may be well to relate what took place at the time. You know that miners have a notion that employers seldom change their managers for the better. I was one of those who they thought made things no better; so when the change took place, up came the men out of the pit, and stated to the master that the fire (explosive gas) was in their places. The fireman being there at the time, and hearing what they had got to say, and having just come up the pit from the workings, said to one—" Well, Jack, what's thou come up for?" Jack—" I reckon we've come up for fire." Fireman—" Is there any fire in thy place ?" Jack—" No, but there is in others, I suppose." So he (the fireman) said to another—" Well, Bill, what's thou come up for ?" Bill—" I have come for fire, like others." Fireman—" Is there any fire in thy place ?" Bill—" No; there is no fire in my place, but there is in others, I suppose." So the fireman questioned Ned, Tom, Bob, Sam, and Charley, all in a similar manner, and each was able to work in his own place with safety, but had come up because " others could not work for fire."

Son: Did you say anything to them, father, all the time ?—Father: I allowed them to say all they had to say, as I knew that truth will always make its way. Then, their object having been seen by the master, and by every person there, I said, " You know, men, before the change took place, you had to work with red-hot safety lamps, and some of you had to give up working in your places, because the accumulation of gas was so great that a safety lamp could not burn, and coal was lost, because the quantity of gas was too great to allow you to get it; and gas often exploded in the safety lamps hundreds of yards from the working faces in the waggon roads. I wish to prevent the loss of your lives, as I also may be lost, if you are." If an explosion had taken place, a great number, no doubt, would have been lost.

Son: Did you say anything more?—Father: The master said many heads had many minds; therefore it would be well for them to find a better mode of ventilation, and, no doubt, I should be glad to adopt it; I assured them I would do, with great pleasure.

Son: Did they find, then, a better mode of ventilation?—Father: No; I offered two pounds to any person who would draw me a plan of ventilation as good for their safety as mine; but home they went, and I cannot say whether or not a fight took place on the road, as one said "I should not have come up had it not been for thee; "and another, "I should have been working had it not been for thee, I had no cause to come up;" and so one charged the other for not being at work.

Son: Did they wish to show any more faults in your mode of ventilation?—Father: Yes; they said I had caused the roofs in the tram-roads to fall by changing the mode, and the waggoners said I had made the roads too cold, and they would be "starvan" (starved).

Son: How is it, father, that they would be "starvan," as they called it?—Father: Because before the change they had to work in warm, impure air, but after in cold, pure air. Yet those miners were very good workmen. They were under my charge a long time, and, I believe, sorry afterwards for the opposition they had given, as they knew well it was much better for their safety. Many left when the pit was finished, and engaged at a new colliery in the neighbourhood, where much explosive gas accumulated; and as they had seen the great change for the better in the mode of ventilation I had adopted, I was often requested by them to engage with their new master, as they had great fears of an explosion, which, they said, would no doubt cause great loss, but would be prevented by adopting the improved mode of ventilating by separate currents of air.

Son: You did not engage, I think, with their master?—Father: No. I had a note from him, with a request to see him, and he assured me if I wanted a situation he would engage me; but as I had a situation, and had no wish to change, and as my employer was in the same mind, I remained where I was.

Son: I am very glad, father, you have not had any loss of life, and that the men knew your mode was the best for the preservation of their lives. I shall be glad, now, to have a little conversation in reference to the friction of the air in mines.—Father: I shall be glad to give you all the information possible in reference to the "friction" of the air, as it is a very interesting subject.

The Friction of the Air in Mines, and several ways shown by which it is produced.

Son: Friction is produced, I understand, father, by rubbing or dragging one body against another?—Father: Anything dragged along or rubbed against another thing produces friction. To illustrate the case more clearly, I will show you that friction may be produced in several ways. Firstly, a ball will not roll the same distance on gravel as if rolled on ice, because on the ice there are fewer obstacles than on the gravel; therefore, it is the rubbing or friction of the ball against the gravel which retards its progress. Secondly, a break pressed against a flywheel when in motion produces friction; and, more weight or pressure added to the break against the flywheel, will increase the friction until the flywheel is at a standstill. Thirdly, in proportion to the surface rubbed, so is friction produced—that is, if only one square yard of surface is rubbed, the friction will only be one-fourth of that caused by rubbing four square yards of surface. Fourthly, friction is diminished or increased in proportion to the velocity it travels at; by doubling the velocity you increase the friction four-fold; that is to say, if a vessel at sea can only be propelled 20 miles in a certain space of time by, say, an engine of 100 horse-power, it will require an engine of 400 horse-power to propel it the same distance in half the time, because friction increases in proportion to the square of the velocity.

Son: What do you wish me to understand, father, by the rolling of the ball on the rough gravel, the pressure of the break on the flywheel, the difference of friction produced by the large and less space of surface rubbed, and the increased power required to propel a vessel to travel at a double velocity; that is, am I to understand anything in reference to the friction of the air in mines by the same?—Father: By the above, I hope to show you how friction of the air in mines is produced in four differen ways. In passing air through and around the workings of a mine, it presses against the roof, floor, and sides, and, by such pressing and force, friction is produced; and so great is the friction of the air in some air-gates that it may be heard to make a noise or sound as it rushes through them. Therefore, if air-gates be not smooth, even, level, and free from obstructions, but are rough, rugged, unequal, and not regular, the air-passages will produce more friction than if smooth.

Son: I see by this, that if an air-passage be smooth, the same air will rush through it with less friction than if rough, just as a ball would roll on the ice with less friction than on gravel.—Father: Yes; and the more the air is compressed through the workings, the more the friction is produced by the compression; and, if air is propelled around six groups of miners, the friction, drag, or the rubbing of that air against the roof, floor, and sides, will be much greater than the friction produced by conducting the said air around one division of miners; and, as the flywheel comes to a standstill by the great friction or weight of the break upon it, so, also, will air, if too compressed, from being compelled to drag, or rub through a large space of surface, come to a standstill.

The power of the Furnace, and the quantity of Air produced by an increased power.

Son: I also see, father, that, as there is more friction produced in rubbing four square yards of surface than one, so is there more friction produced by conducting air around six divisions of miners than one; and, as you say, the flywheel comes to a stand by the great friction of the break, so will air also in mines come to a stand, if the distance which causes the pressure be too great for it to travel. But, father, is there not another way by which friction of the air in mines may be seen—that is, by its velocity?—Father: If you cause air to travel at a great velocity, you very much increase the friction. You have seen, no doubt, ships at sea, or vessels in a canal, propelled by the force or power of the wind, at a great velocity, because, the force of the wind against the vessels, which propelled them forward, was very great. Therefore, to propel a vessel forward at the same velocity, if there were no force of wind against it, would require an engine of great power to do it. Well, if the force of the wind which propelled the vessels forward at such velocity were reduced three-fourths, the vessels would only travel at one-half the velocity. So in like manner is ventilation produced in mines. If 20,000 feet of air can only be produced for the workings of a mine per minute by the power or temperature of a furnace, it will require the furnace to be increased in power fourfold, to produce double the quantity of air, because, as before stated, the friction of the air increases in the same ratio as the force, and the force increases as the square of the velocity. As that is the case, it requires four times the temperature to produce double the quantity of air, and sixteen times the temperature to produce four times the quantity of air, because the force of the air against the roof, floor, and sides, which produce the friction, is very much increased by the velocity.

Son: Suppose, father, two divisions to be of unequal lengths, one 800 yards from the down-cast to the up-cast, the other only 400 yards, and the area of the air passages each to be alike, nine feet. I wish to know why air rushes with greater velocity on the shorter route than on the longer one?—Father: Because there is less friction in one than in the other; or, in other words, the balance of friction in the two is not equal; therefore, as an increased velocity produces friction, and there is less friction in the shorter route, the air rushes in to equal the balance of friction between the longer and shorter route.

Son: I shall be glad to know, father, what quantity of air would rush into each gateway to balance the friction in the two?—Father: Well, if you had, say, 12,672 cubic feet of air for the two divisions, to produce the same friction in the shorter division as that in the longer one, it would require nearly 7,524 cubic feet of air to rush in, and the longer would require only 5,148 cubic feet; thus, the longer division would lose 1,188 feet, and the other would gain the same quantity of air over and above its own quantity. By this it will be seen that there is a great loss of air from the workings when air is propelled around a great number of works, as the furnace would have produced the same quantity of air for the longer route as the shorter one, had it not been for the extra friction. One thing I wish to impress on your mind—that air will always balance the friction in each and all divisions. The distance the air has to travel and the quantity of air in each division may not be equal, but air will rush more or less into all parts until the balance of friction in all be equal.

The great Friction of the Air produced by one mode of Ventilation, and how the friction may be reduced by another.

Son: I see, father, by conducting air around a long route of workings, such workings will lose much air; also, to form one large current of air from many divisions, and propel the whole through one air-gate, the friction of that air must be very great?—Father: To show the increased friction by ventilating a great number of works with a large current of air, I will suppose 38,016 cubic feet of air to ventilate the workings of a mine, in which there are, say, six separate groups of miners to ventilate, and the area of each gateway is nine feet. To split the whole wind into parts, and ventilate each group of miners separately, each would have, per minute, 6,336 cubic feet of air. This being the case, the air would rush into each gateway, and through the workings at the rate of eight miles per hour, and its force on one square foot would be a little more than five ounces. Well, but if all the six divisions formed one large wind of 38,016 cubic feet, and the whole quantity had to pass, per minute, through the nine feet area around all the six divisions, the said current would have to travel at the rate of 48 miles per hour, and the force of the current on one square foot would be 11¼lbs.

Son: There is a very great difference, father, between the one and the other—the force of separate currents only 5oz., and the other 11¼lbs. Yet there is the same quantity of air produced by one mode as by the other. The air rushes with a force 36 times greater than if each part be ventilated separately; therefore, what difference is there, father, between the friction of one mode and the friction of the other?—Father: Well, by one mode, you see, the air travels around six parts, but by the other mode only around one. Therefore, suppose one travels 1,000 yards and the other 3,000 yards, the distance would be two-thirds greater by one than by the other. By this the friction, in proportion to the distance, will be 72 times greater in one than in the other, and 36 for the great force or velocity added to the 72 will show the friction near 108 times greater in one than in the other. Because the friction in this case is of two kinds—one is in proportion to its force or velocity, the other in proportion to the distance it travels.

Son: To enlarge the air-gates would prevent this great friction of the air.—Father: Yes, but look at the great expenditure; air-gates would require enlarging from nine feet to 54 feet.

Son: I see, father, the expenditure would be very great, and the expenditure in furnace power to overcome that amount of friction would also be very great, because the furnace, I see, in proportion to its power, overcomes a certain amount of friction.—Father: Yes. If the friction of the air be very great the furnace will overcome it, but produce a less quantum of air; but if the friction be not very great—that is, if the air-gates be large enough for the air to travel—the furnace will produce a larger quantum of air for the said amount of friction; therefore, there is less air. But the furnace, in proportion to its power, always overcomes the said amount of friction.

Son: I am very glad, father, for this information on the friction of the air in mines. I wish to have a little information now in reference to the working out of coal in mines, and why so many ways or plans are adopted.—Father: It is my wish to give you all the information possible; and when we next meet I shall have great pleasure in doing so.

Several modes or ways by which Coal is worked out in Mines, and why so many methods are adopted.

Son: You have seen and adopted, no doubt, father, many ways of working out coal since you first were engaged in coal mining.—Father: Yes, I have adopted many ways, because I know that the same mode of working out coal will not answer with safety and economy in all mines. One plan of working it out may answer well at one colliery, but not in every one.

Son: Why will not the mode which may answer well at one colliery, answer in all mines? Father: Because the nature of the roof, floor, and coal is not alike: neither is the pressure nor the accumulation of gas in the coal, floor, and roof alike in all.

Son: Does the roof, floor, coal, and pressure vary much in mines?—Father: Yes, at one colliery the floor is soft, but hard at another; in other mines the roof and floor are both soft, in others both hard; the floor heaves in some mines, but in others not so; in some mines coal is hard, but soft in others; the pressure of the roof upon the workings is very great at one colliery, but not so great at another; gas in the roof, &c., prevents at some collieries, tram-gates being cut through the whole coal to the extremity, as there would be no end of the falling in of the roads by cutting them in the whole coal; yet, in other mines, if the roads are not so cut, they would fall very much; in some mines the seam of coal is very thick, but in others very thin; also, the coal lays flat in some mines, but dips, or rises very much in others; here are many throws, faults, troubles, veins, seams, bad and soft coal, but there the coal is all good, and nothing to impede plans in operation. Single tram-gates may be cut through the whole coal at some collieries to a great extent beyond the current of air, by which managers in charge of the same will be able to adopt the plan in contemplation, while the accumulation of gas in other mines will not allow tram-roads or narrow-work to advance two feet beyond the current. The disadvantages to contend with in some mines are so numerous that a good profitable mode of working out the coal cannot be adopted.

Son: I see now, father, why so many plans are adopted. As you say, one is because the floor is hard, another because it is soft; one is adapted for this thing, and another that. Therefore I think no person should condemn any mode of working out coal unless he knows well the nature of the roof, floor, and coal, and all the disadvantages connected therewith; as the plan he condemns may be worked with economy and safety where it is adopted, and also may be the best that can be used for that seam of coal.—Father: Yet many plans adopted are not useful, as they have been adopted by managers not having a proper knowledge of the nature of things. Therefore every underlooker or manager of mines should have a good knowledge of the nature of the roof, floor, coal, &c.; and also a good foresight of his contemplated plans. He should have such foresight as to see in his mind's eye the plan at work before he adopts it. If not, he cannot see his way clear before him as he should do, but, like a person bewildered in a thick mist, adopts unmatured plans, which will end in injury to the men under him and loss to his employer. His object should always be to adopt the best plan to suit the seam of coal to be worked out, and not to change because he may see a good plan of working coal drawn well on paper.

Son: I presume, father, some mines require much care and attention to produce a good profit for the employer, and ensure safety to the men?—Father: Yes, some mines cannot be worked with a good profit if all the plans in use are adopted. So changeable is the roof, &c., in mines, that in some of them no plan appears to answer well. I have known—and had to manage—mines where, in one pit, the plan which would answer well on the north part, would not answer on the south.

Son: By what you say, I clearly see one colliery will be much better to manage than another. Therefore, no doubt, father, some managers have got a good name, not because their knowledge of mines was great, but because they have got a good colliery to manage; while others, with a good knowledge of mining, have been disgraced, because neither they nor any one else were able to make the colliery under their charge pay a good profit to their employer. As you have clearly shown the cause why so many ways of working out coal are adopted—I shall be glad to know, father, how or by what way coal is worked out?—Father: One mode is pillar, stoop, or room-working; long-wall working another; bank or wide working another; and others work coal out in drifts, yet each and all the modes vary in the way of working.

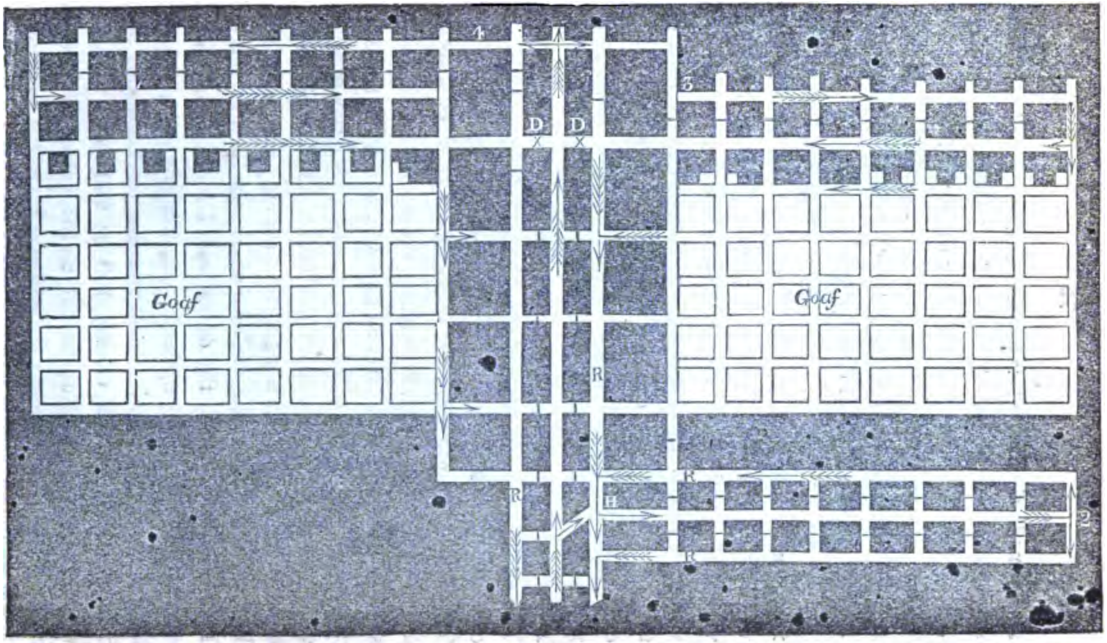
Son: What am I to understand, father, by pillar, stoop, or room-working; that is, in what way is coal worked under those methods?—Father: Pillar-working is adopted in several mining districts, but universally so in the north of England. To get coal out in pillars narrow work is cut in the whole coal into square blocks, the narrow work being cut endways and crossways of the coal, by which square blocks of coal are formed. This mode will find room or places for a great number of miners—some in cutting narrow places, others in working out pillars, the pillars always being worked out next to the old gob or goaf; that is, one pillar worked out next to the last one worked out.

Son: Are the blocks or pillars square, and all of the same size in every mine?—Father: No, in some mines they are square, but in others they are not; neither are all the pillars of one size; they are cut large or small, to suit the seam of coal, roof, or floor, where such pillar-working is adopted. If you inspect plan No. 7 it will give you a better knowledge how or by what way pillar-working is adopted.

Son: I see by the plan that narrow places are cut in the whole coal, in two directions, which will, I see, make square blocks of coal to be worked out. Then this, father, is the plan of coal-working universally adopted in the north of England?—Father: Yes, it is the mode they adopt, and plan No. 3, page 36, also shows pillar-working.

Son: Yet, the mode of ventilation on plan 3 is not the same

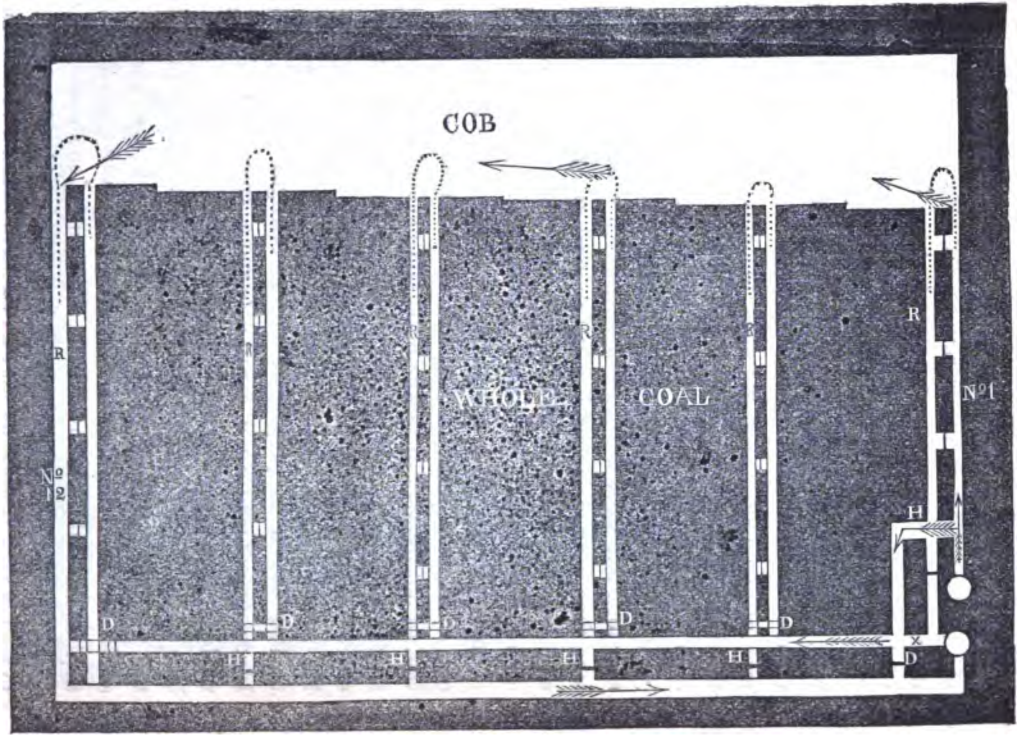
PLAN No. 7.



as the mode shown on this plan?—Father: No, this plan shows split winds, and not like plan No. 3, a mixture of winds. If you inspect this plan you will find four divisions for the number of works.—See Nos. 2, 3, and 4, where the air is divided. The letter H shows the overthrows. The letters R R, regulators, and D D, show the position of the doors.

Son: I am glad, father, for the knowledge I have received from you. I think I can see, in my "mind's eye," how pillar-working is adopted; but how is coal got out by long-wall working?—Father: In long-wall there are many ways adopted. One is to work a great number of tram-roads, or narrow places, through the whole coal to the extremity of the block of coal to be worked out; after which, say 100 or 200 yards, or more, is brought back, and the gob, or goaf, left behind. Plan No. 8 is a representation of the said mode of working. You see the whole coal, and tram-gates cut through the said coal, and also the gob or goaf where coal is got out left behind. The mode of ventilating the said workings is to conduct the air in at No. 1 gateway, from there across the whole breadth of all the working faces to No. 12 gateway, and from there in one current to the up-cast. As before stated, a large quantity of gases are always collected by this mode. Yet, each part may be ventilated separately if overthrows are only fixed at the letters H H, and each separate division of air regulated at the letters R R. In this case, all the doors would have to be removed, except the one near the up-cast. Yet, this is not the only way of long-wall working, as others commence at the beginning to work out the large breadth of, say 100 or 200 yards of coal, the whole breadth being worked out to the extremity, the tram-roads being made through the gob or goaf, to the working face, as the said face extends into the extremity of the mine.

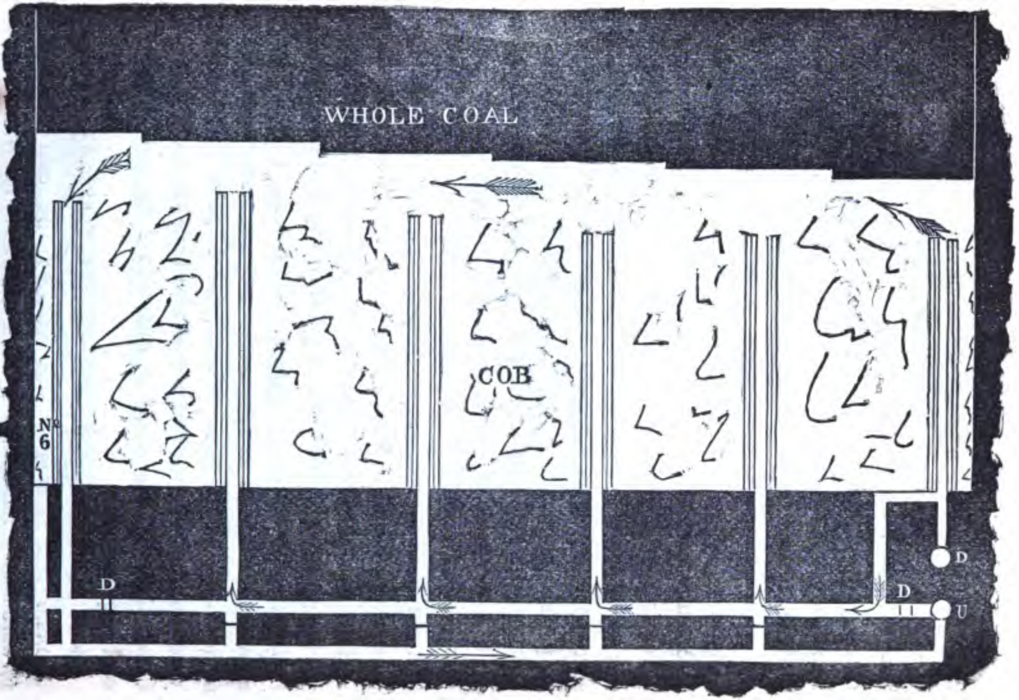
PLAN No. 8.



Son: How, father, are tram-roads cut or made through the old gobs or goafs to the working face? Is there not great danger in so working coal out? And, also, are tram-roads made through the gobs a great distance to the working face?—Father: To make tram-roads through the gob a four feet stone wall, or thereabouts, is built upon each side of the road, as the coal or working face extends forwards. These stone walls prevent the roof falling in, until the great pressure causes the roof and floor to nearly meet, by which the floor is either cut up or the roof cut down in the roads to make them (as the roof and floor meet) of the proper area. When finished, they look like stone-drifts or tunnels, which will stand good a long time. As to danger, it is not so great as by many other modes of coal working; and the said roads may be and are cut a great distance through the old gobs or goafs.

Son: You say 100 or 200 yards, or more, of coal is worked out all in one breadth. Can this large breadth of coal be worked out in every mine where the said mode of coal working is adopted—that is, can you see all the men at work from one end of this large breadth of the face to the other?—Father: No, not in all, you cannot. The breadth of the face of coal worked out is in proportion to the strength of the roof. If you inspect plan No. 9, it will give you a knowledge of this mode of working. The whole coal or the face of the workings has to be got through the old gob. The mode of ventilating the workings is to pass the air fresh into every gateway, except at No. 6, at which place the whole of the air meets; after ventilating the said place onward, the air goes in one current to the up-cast. This mode of ventilation may be said to be similar to plan No. 2, page 32, by which pure air is mixed with impure

PLAN No. 9.



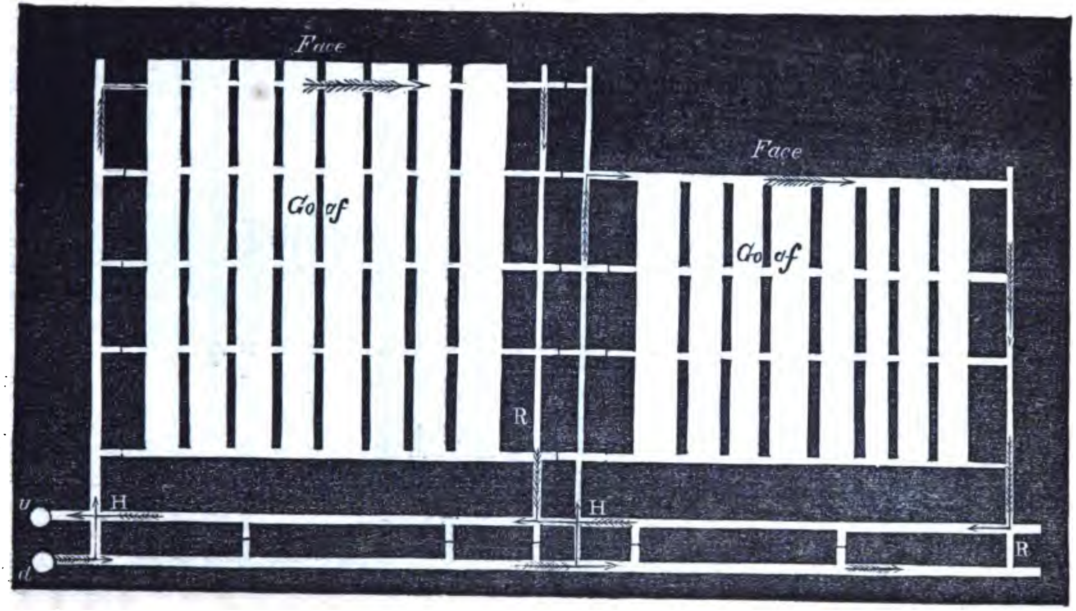
air. Yet, this mode of ventilation is not good, as the whole of the gases generated in all the workings are collected to No. 6 working place, so that an explosion there would affect every other part of the mine. Therefore, ventilate the same separately, by passing air fresh up one gateway, and return it on the other. As to the mode of working out the coal, when the strength of the roof, &c., will not allow the whole breadth to be worked out at once the breadth is diminished accordingly; that is, two tram-gates work out their own breadth, advancing first into the extremity, other breadths follow up, one advancing a short space before another, by which the pressure upon the working faces is diminished, or equalized in all parts.

Son: Then I presume, father, when narrow places or tram-roads are worked through the whole coal to the extremity of the coal, the whole breadth of the 100 or 200 yards is not brought back all at once?—Father; No, not always so; it is often worked back in lengths, one before the other.

Son: I am obliged, father, for the information on long-wall working. I now wish to know by what way coal is worked out by bank or wide work?—Father: Wide work or bank work is similar to long-wall or long work, only the tram-roads are not made to the working face through the old gobs, but 60 or 100 yards of coal are worked out in one breadth, the tram-roads being cut in the whole coal on each side of the wide breadth of coal worked out.

Son: Is all this width of 60 or 100 yards got out, that is, is none left to support the roof, as the coal is worked forwards into the extremity?—Father: In many mines the whole of it is worked out; and in some mines a rib of coal, one

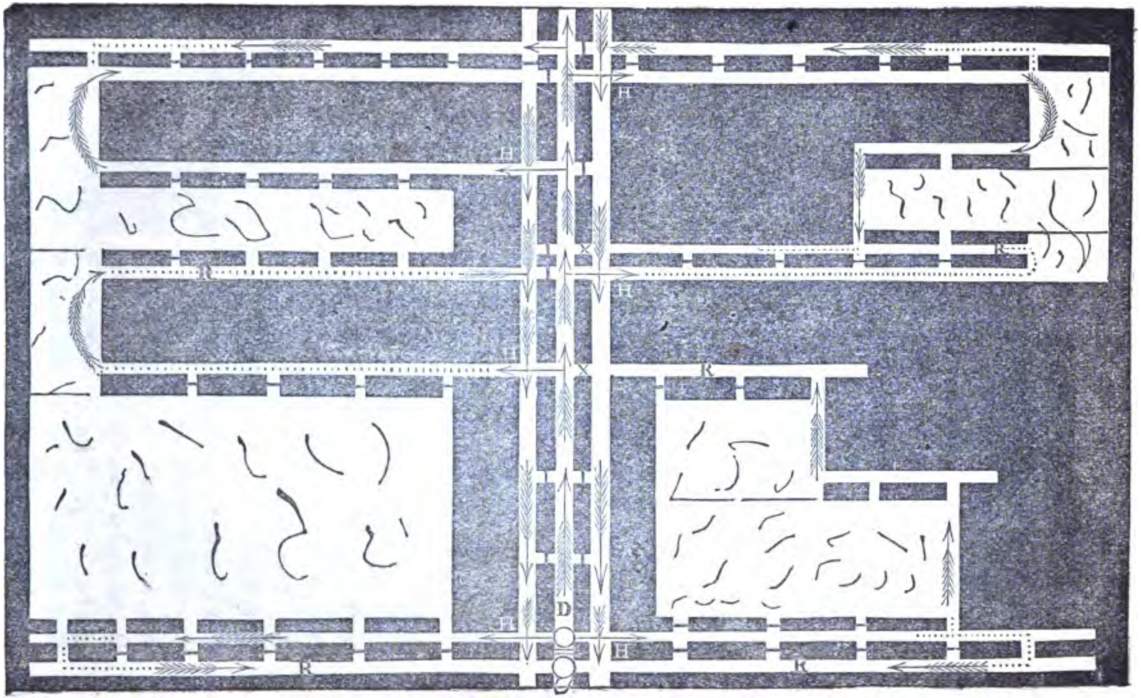
PLAN No. 10.



yard in width, is left between every 10 yards, to support the roof—a hole being made through those ribs or posts of coal through which waggoners pass and repass with coals from the working face, and as the bank face advances, new holes are made through the ribs or posts, by which a new road is made next to the working face. You will have a better knowledge of the mode of working by inspecting plan No. 10, which is a representation of this method. Ribs of coal are left, you see, between each working place, and as the face advances, new roads are cut through the ribs of coal across all the working places, and in like manner new roads are formed as the face advances by being worked out. This mode of coal getting may also be seen in plan No. 4, page 40, as the two plans are similar, except that in one the coal is worked out from the commencement to the extremity of the block of coal, and in the other the working is commenced at the extremity, and is continued in the return homeward to the commencement of the working. Also the mode of ventilation is, on this plan No. 10, to have separate windings for each bank or working place.

Son: You say, father, to work out coal in bank or wide work, 60 yards or more is got out in one breadth and worked away from the commencement to the extremity of the block of coal; also for the conveyance of coal from the working faces, tram-gates are made in the whole coal on each side of the large breadth of coal worked out. I wish to know, father, if this is the only way of getting coal out in bank or wide work?—Father: It is not the only way. In some mines the whole 60 yards of breadth is not worked out at once, but one-half only. The other half is followed up a little behind

PLAN No. 11.



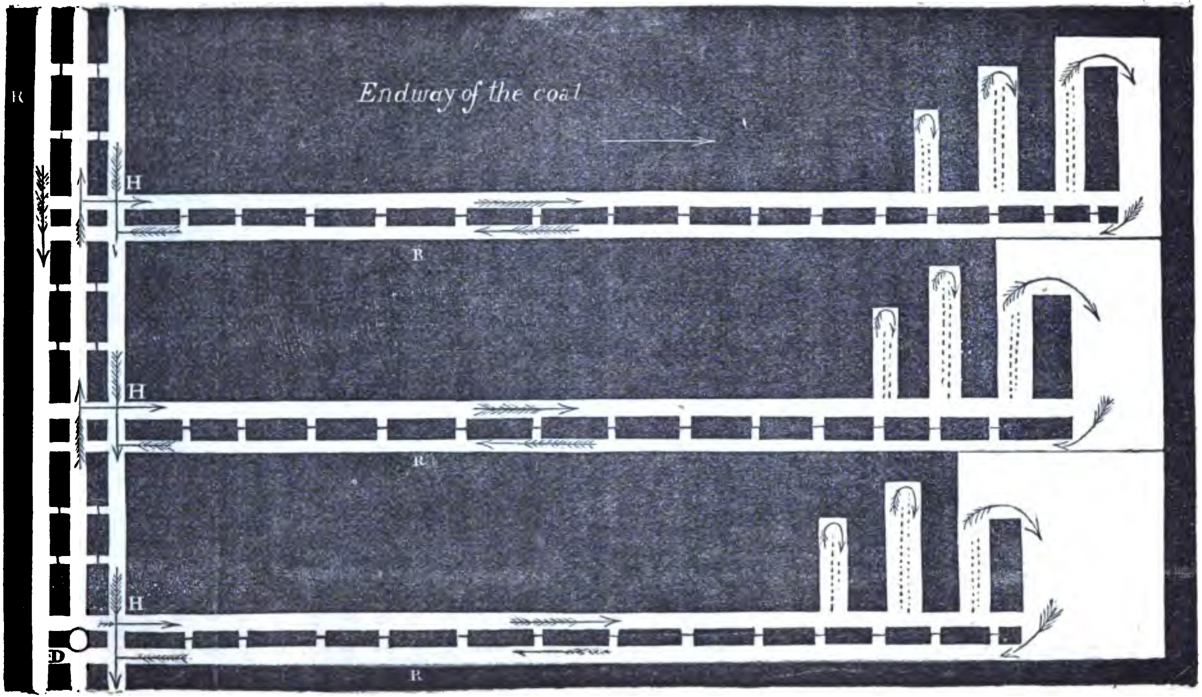
the first one, or if the whole breadth is worked out, another breadth, of say 30 or 40 yards, follows up the first. You will see the mode of coal working in plan No. 11. The whole breadth of coal is not worked out all at once, but one breadth takes the advance, and the other breadth follows after, tram-gates for the conveyance of the coal being cut in the whole coal on each side of the breadth worked out. Also the mode of ventilation is that of split winds.

Son: Is there any other way by which coal is worked out in wide work?—Father: Yes, the following:—A great number of tram-gates are cut on the "end" of the coal to the extremity of the block to be worked out, after which coal is worked away on each tram-gate homeward or backward. Now, as tram-gates are cut in this case on the "endway" of the coal, the coal is worked away in breadths between tram-gate and tram-gate,—that is, a wide place from 10 to 20 yards in width is worked out, between one tram-gate and another, on the boardway of the coal. When finished another is worked away next to the last one, and so it is continued until the whole of the coal is worked away backward from the extremity. You will see a representation of this mode of working out coal in plan No. 2, page 32.

Son: I see by this mode, father, that as tram-gates are cut in the whole coal in plan No. 2, to the extremity, and worked back in wide places, the goaf or gob will be left behind.—Father: Yes. This mode is often called heading or ending work, because narrow places or tram-gates are cut, not on the boardway of the coal, as in plan No. 11, but on the endway of it.

Son: Very good, father; but how is coal worked out in

PLAN No. 12.



drifts?—Father: The mode of working away coal in drifts is similar to that shown in plan No. 2, it being worked away in headings or endings. Narrow places are cut, as before, on the endway of the coal, after which blocks of coal from six to ten yards in width are worked out between one heading or tram-gate and another, a pillar or post of coal being left between two drifts, and pillars being worked backward (after the drifts are finished) to the tram-gate. For your better information I must again refer you to plan No. 12, as you will by it have a better knowledge of the said mode of working. The mode of ventilating the works is that of separate windings.

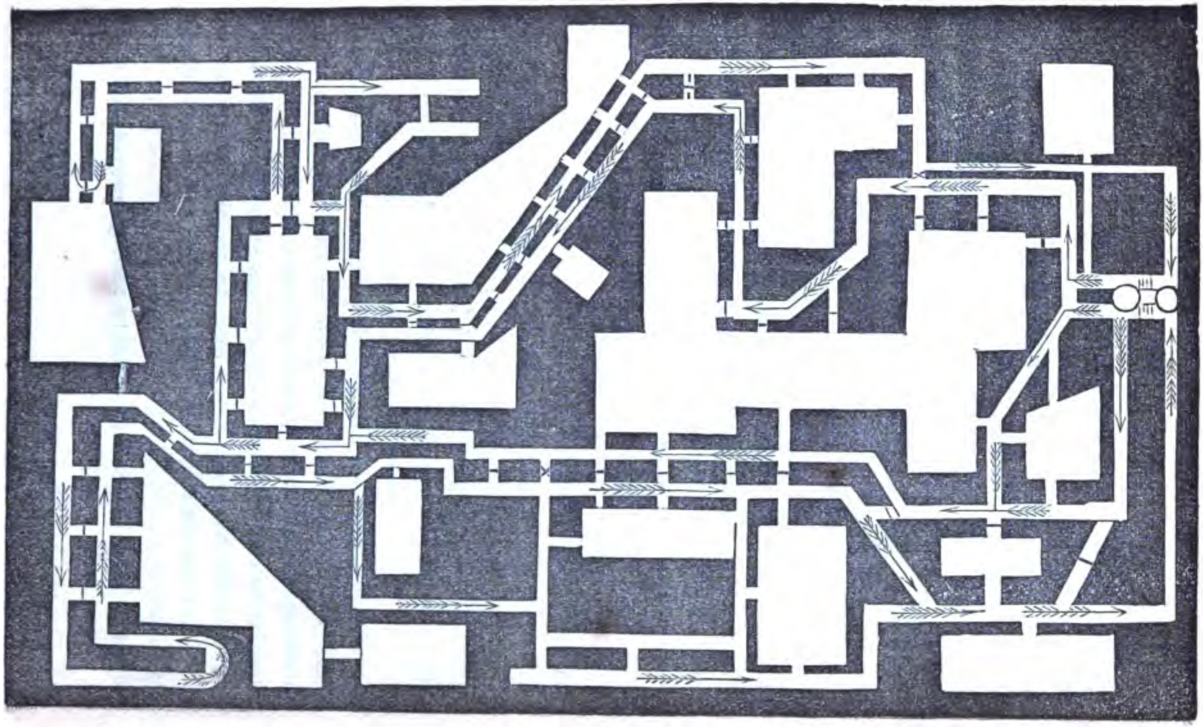
Son: What distance may these drifts be worked in from the tram-gates? and what width are the pillars or posts? Father: The distance of the drifts worked in and the width of pillars vary much. The width of a pillar varies from six to ten yards or more, and the distance of drifts worked in also varies from ten to forty yards or more.

Son: Is there any other mode, father, by which coal is worked out?—Father: There are other ways of getting coal, but in many there is no regularity.

Son: Why is there no regularity in the mode of getting coal out in some mines?—Father: Because it is worked out from any place, anywhere, and in any way. If you wish to see a plan of an irregular working, an inspection of plan No. 13 will give you a little knowledge of one such as I have described.

Son: What is the object managers wish to accomplish by so working or getting coal?—Father: They have several objects in view. One is to get a large quantity of coal, and produce a good profit for the employer. Another is to impress on the

PLAN No. 13.



public and the employer's mind that they excel others in management.

Son: Is it not every manager's duty to get out a large quantity of coal, and, if possible, to excel others in the management of mines, by which the employer may be profited?—Father: Yes; but if coal is not got out in a proper way, the profit produced will only be of short duration, as often large blocks of coal are left between two "goafs" or "gobs;" and, to work such blocks of coal out, there is often loss of life, great expenditure, much loss of coal, and, for the conveyance of the coal, roads of a circuitous route have often to be made.

Son: You know, and have seen, then, mines worked in the way you state?—Father: Yes; one colliery in particular, which would have been a good colliery for a number of years had it only been properly managed. It cost many thousands of pounds; but now the proprietors would be glad for any person to take it off their hands.

Son: Was the manager of the colliery a person who had a good knowledge of mines?—Father: He professes to have much knowledge of mines, as I know he takes tradesmen's sons as pupils, to qualify them for underground managers.

Son: Is the manager still at the same colliery, or was he discharged?—Father: Discharged—no; he had produced too good a profit in the short time he had been there to be discharged, and it would have been impossible for any person to impress on the minds of the employers anything disrespectful of him; yet he knew better than to remain there when the inside of the pie was got out, and another colliery was offered to him.

Son: Then those who came to manage the colliery after him would not be able to make it pay so well?—Father: No; neither he nor any one else would ever be able to make the colliery pay a good profit afterwards.

Son: I think if his pupils never have any practical knowledge of mines, but what he can give, it will be very little they will know of mines.—Father: If a person intends to be expert in the management of the underground workings of mines, he must be taught in a mine and not out of it; or he will have nearly the same knowledge of a mine as a mine will have of him. I have been in mines more than thirty years, and yet I find things in which I can profit constantly occurring.

Son: Are there no good, practical, and talented men to be found in mines to manage the underground workings? and if so, is it not a disgrace to place a tradesman's son in such an office?—Father: There are in mines many practical men, and men of first-class knowledge, well able to take the management of the underground workings, but they are not allowed to do so. A tradesman's son must take that office, and he who has served all his lifetime in mines must ask one of those pupil-managers how the works are to be conducted, when he (the practical man) knows much better himself.

Son: I think it is time, father, that something was done to place the right man in the right place. You would be thought a strange person to take the command of a ship at sea, and to have a great number of lives, and a large amount of property under your charge, without your having a practical knowledge of navigation.—Father: Yes; but a practical miner is down, and a great number of people would keep him down. Their object is to get themselves, or some one related to them, into the place which would elevate the miner, or practical man. But I hope the day is not far distant when every practical man who has got the abilities in him to manage will be brought out from the ranks, and the whole form one institute, in which they will receive a knowledge of dialling, of laying the working of a mine on plan, of gases—how they accumulate, of ventilation, of working out coal in mines, &c., &c., and every one shall pass through an examination, after which he shall be recommended to colliery proprietors in the whole kingdom.

Son: Should not underground managers have a knowledge of the capabilities of the workmen under their charge, so as to appoint the right man to the right place?—Father: Yes, because some workmen have a better knowledge than others of gases, ventilation, fixing doors, overthrows, stoppings, bars, props, rails, laying and preparing roads, &c.

Son: They should also have, I think, a good judgment of every person's work, so as to give to every person his right and due, and not to show their management by deducting the workmen's wages, as some, I fear, often do; but if they will show a good profit for their employers let it be by excelling others in management.—Father: You are right; if a person can show his employer no profit but what he can take off a poor man's wages, the sooner he is removed the better; his object should always be to better the employed as well as the employer, to do right to all.

Son: Is not the labour in mines much better to do in one part, and attended with more profit to the miner, than the labour in another part?—Father: Yes; and such being the case, the manager ought to give every miner an equal share of this better work, as far as it is possible, and not give the whole of it to those persons who may have obtained his favour by spending a convivial hour or two with him after the toils of the day or week. Fault-finders or tale bearers have all the better work.

The Best and most Competent Persons to Manage the Underground Workings of Mines.

Son: Who do you think are most competent, father, to manage the underground workings of mines?—Father: Those persons who have a knowledge of the practical part, and also of the theory of mining. Such managers have a double advantage, as their knowledge has been practically acquired. They cannot be equalled by any other class of men. Therefore, I would recommend every one in charge of mines to obtain a knowledge of the theory and also of the practical part.

Son: I think those in charge of mines, father, should be steady, sober, and attentive, having good knowledge, foresight, and stability, because mines are constantly changing, and things taking place which require much attention and care.—Father: Yes, they should have a good knowledge of mines and mining before they take charge of so many lives and so much property; they should be men that will go first into a mine when an explosion of fire-damp has taken place. A good manager would not send others where he would not go himself; he will go first, and see the cause, and risk his own life rather than the lives of those under his charge, because others, not having a proper knowledge of their work and the mode of ventilation, might not do right, from having too great a fear of doing wrong, by which they might cause the loss of their own lives, as well as those they were in search of.

Son: You say it is your wish, father, for every practical man, who has got in him the abilities to manage the underground workings of mines (as many practical men in mines, you say, have) to be brought out from the ranks, and for a mining institute to be formed, and that from such institute every one should pass an examination as to his qualification for underground manager. Would you, therefore, have every mining district to call out the men who have got a good knowledge of mining, and give them practical information on ventilation, gases, working out coal, dialling, and laying the workings on a plan, &c., such information being had in their own districts, after which they could be recommended for examination?—Father: Yes, I think it would be well for every district to have days of meeting for the men to receive information in their own district to qualify them, as the abilities of a person may be very good, but he may be too poor to often attend an institute which is perhaps at a distance. After the men have got to a state of efficiency, they should be recommended for examination to the institute, or to some other institution appointed for their examination.

Son: I also think, father, that every one in charge of the underground workings in mines should have a practical knowledge; and also pass an examination as to his qualification and knowledge of mines; a number of lives should not be placed under the charge of a tradesman's son because he has been able to pay a good premium as a pupil for two or three years. He may profess to know a great deal about mines, but, in truth, it will be very little he will know of them; neither will he be often seen in a mine—his information of them will have to be given to him by others. Father: If a tradesman's son manages any work, it should be the surface work.

The Mode of Dialling.

Son: You say, father, underground managers should have a knowledge of dialling, and drawing the workings of a mine on a plan. I wish to know how you would have them to get this knowledge, as few persons will show a poor miner how it is accomplished, be his abilities ever so good?—Father: I know few persons will show a poor man with a practical knowledge of mines how it is accomplished. It cost me a good deal of money, and I had much to do to prevail upon a person to give me the information; I have often had letters from practical men asking for information as to how it was accomplished, and I have been sorry not to have been able to give them that information by letter that I could have done had I been in their company; the knowledge must be got by practice—seeing and doing the work. It would be very difficult to understand and get a knowledge of it by reading and hearing.

Son: Would it take a long time for a person to get the necessary knowledge?—Father: No. It would soon be obtained if those who wish to acquire it could only have a little practice.

Son: But I fear no one, father, would show a number of miners the way by which dialling is accomplished in mines; they would not take the dial into a mine and show them.—Father: There is no reason why they should take it into a mine to obtain this knowledge; the information can be got on the surface; and a miner would very soon understand how it was accomplished in a mine, having a practical knowledge of the underground workings.

Son: I should be glad to know and understand the mode of dialling, and laying the workings of a mine on a plan, if you can give me that information?—Father: I hope to give you a knowledge of dialling, and also, of laying the workings of a mine on a plan, if you will attend to what I have got to say, and inspect the figures I shall show you. The figures will give you a better knowledge, as I shall give an explanation of them.

Son: Be assured, father, it will be my endeavour and delight to attend to the instructions you give, as I very much desire to know how to dial, and how to lay the workings of a mine on a plan.—Father: Figure No. 14 is a representation of the compass or dial. There are, you see, figures "around" the outer circle which give the number of degrees around the dial. You will see, also, figures around the inner circle; these give the number of degrees between North and East; and also, between North and West. It will likewise give the number of degrees between South and West, and between South and East. For example, there are 360 degrees around the whole outer circle of the dial, but between North and West in the inner circle, there are 90 degrees. Also 90 degrees between North and East; 90 between South and West; and the same number between South and East.

Son: I see there are, father, two rounds of figures on the dial; those figures around the whole outer circle show 360 degrees; but those around the inner circle show 90 four times repeated.—Father: Yes, and when you read off those 360 degrees around the outer circle of the dial, you will have to make an entry of the number, whatever it may be; but if you wish to know and make an entry of the number of degrees between North and West, or between South and East, you will have to read off those degrees or figures around the inner circle of the dial, and give the number of degrees between North and West, &c., whatever that number may be.

Son: Very good, father, I understand the figures on the dial, but what about the dial needle? I see it vibrates, or works backward and forward at every turn or movement of the dial.—Father: The cause of the vibration of the needle is, that it is a magnetic needle, which is balanced upon the point of a pivot, so that it can vibrate without friction towards the direction to which it is most attracted. Its tendency is always to point towards the North. That is to say, the needle may vibrate backward and forward when the dial is removed, but it will soon come to a stand-still when the dial is at rest, and one end will point due North, and the other, of course, due South.

Son: Suppose, father, I take the dial, and place it at any point I may think proper, and look at an object at a distance; how am I to fix the dial so as to ascertain the degree North or South, of the object, from the situation of the dial?—Father: Before I proceed to show you how to fix the dial, and to understand its indications, I would beg of you to have a look once more at the dial. You see a letter N next to one of the sights, and also, a letter S near the other sight. Well, when you fix the dial, always have the sight N next to the object you look at, and look through the sight S. That is in going forward. If you fix a dial in a mine, see and always have the sight or letter N next to the working face, and the sight S next to the pit from whence you go, looking through the sight at objects which convey you from the pit into the workings, and so continue to look through at the letter S, sight after sight, until you come to the working face. But if in case you take a back sight at an object towards the pit, look through the sight at the letter N:—that is, keep the dial fixed so that the sight at the letter N will point into the workings, and the sight at S will point to the pit.

Son: Very good; I am glad, father, for the information as to how to fix the dial, which, I think, I now thoroughly understand, but how am I to know the number of degrees between one object and another?—Father: You must fix the dial in the way described, and look at objects through the sight S (if such objects convey you from the pit into the workings); after the needle has come to a perfect standstill, look at the north-end of the needle (as one end always, as before stated, points north and the other south,) and see what degree of the dial the point of the needle is at, and whatever the figure may be, make an entry of it in your book, for it is the number of degrees between you and the object.

Son: Suppose the north end of the needle should stand at 63½ degrees, will it be 63½ degrees north-east?—Father: Yes. The degrees between north and east are the same in this case as those degrees around the outer circle of the dial, yet it is not requisite at all times to make an entry in your book of the two rounds of figures. I only give you a knowledge how to read off the dial by two ways, so that, if required, you will be able to read it off by either way; that is, you will know the dial by its degrees between north-east or south-west, &c. Yet, as you are only a learner, you will understand the degrees of the dial much better if you only make an entry of the outer circle of figures.

Son: Then if I find the point of the needle stands at, say 63½ degrees, when looking at an object, all I have to make an entry of in my book is 63½ degrees to the object. But what am I to understand, by these 63½ degrees?—Father:

Well, the point of the dial needle always stands or points north, therefore, 63½ degrees is away from that north point; that is, you will have turned the sight letter N away from the north point of the needle so far, that a space of 63½ degrees will be between the north end of the needle point and the sight N.

Son: Then if I look at another object through the sight S, and the north-end of the needle stands at 152 degrees, I have only to make an entry of the distance in my book and between object and object?—Father: That is all you have to do. If, on looking at another object, the needle is at a stand-still at 152 degrees, it only shows a greater space between the sight N and the north-point of the needle. And in like manner you may continue to look at objects in several directions, and every object looked at may vary in the number of degrees, more and more, until you come with the sight N round again to the north-point of the needle. Therefore, an object at 152 degrees, would be in the south-east direction at 28 degrees; that is, it would point 28 degrees away from the south-eastward. And in like manner an object at 240 degrees would point in the south-west direction, at 60 degrees between south and west. If you look at an object at, say 320 degrees, the needle point would be at a stand-still at 40 degrees in the north-west direction. There is no necessity (as before stated) for you to bewilder yourself when dialling, by making an entry in your book of the two rounds of figures, unless you think proper, the figures around the outer circle of the dial will do.

Son: I think every person, father, may understand how to fix a dial, and also make a proper entry of the degrees after being informed in this way. But how would you commence to dial the underground workings of a mine?—Father: Suppose you are required to dial workings similar to those on figure 15; you may make if you think proper, a sketch in your book similar to figure 15, or according to the roads cut in the mine; after which, fix the dial in any part of the road, so as to enable you to see the centre of the pit and along the tram-road forward to the cross-roads. At the same time let the dial be so fixed that the letter or sight S will be next to tho shaft, and the sight N next to the working-face, always keeping the dial in the manner described; then look through the sight S, but if you have cause to take a back-sight toward the pit, look through the sight N, and after the needle has come to a stand-still, make an entry of the number of the degree pointed to.

Son: Suppose, father, I find the north-end of the needle point to 63½ degrees?—Father: If so, make an entry on the sketch in your book, similar to the one you see on the figure; you see it shows 63½ degrees, so that it is 63½ degrees north-east. Afterwards measure the length from the pit to the cross-roads.

Son: Suppose I find, father, the length of the road to be forty-five yards?—Father: Then, mark forty-five in figures, similar to those you see on the sketch.

Son: The length, father, being finished, do I remove the dial forward to another object?—Father: Yes; and fix it, if possible, in the centre of the cross-roads, so that you may look forward and into each side road without removing it; but, if you cannot so fix it, on account of iron, towards which the needle is attracted, each road will have to be taken separately, in the way you took the first length from the pit.

Son: Suppose I fix the dial and look forward on the first road, and find the north point of the needle to point at 61 degrees, and the length from the cross-road to the end of the road is forty yards, and I look for the degrees on each side road. One road I find at 152 degrees, and the other 332½; all I have to do, is to make an entry of the figures with the length of each road, one of the lengths being, say forty-five yards, and the other twenty-two yards.—Father: Just so. That will be the way with the degrees around the circle, but those degrees of the quarter circle will be north-east 61, south-east 28, and north-west 27½ degeees.

Son: Then the sketch in my book will be like figure 15?—Father: Just so. Now you have a knowledge of dialling, or how to read off the dial; and if you only attend well to it, you cannot but know the direction of each working part of the mine, and be able to dial forward as the workings of the mine extend, following on from sight to sight, until every sight is dialled from the pit to the extremity of every road in the whole mine.

Son: As I have got a knowledge of dialling, I now wish to have a knowledge, father, how to lay the workings of a mine on a plan; that is, if I had a large sheet of paper, I wish to know on what part of the paper to fix the pit, and how to commence laying the workings?—Father: All you have to do is simply to place upon the paper a mark similar to the letter O, and call that the pit; you may fix the pit on any part of the paper, but as near the centre as possible will be best.

Son: And what have I to do, father, after fixing the pit?—Father: You see a line drawn across the pit in figure 16, do you not?

Son: Yes I do. I also see at one end of the line a letter N, and a letter S at the other end. The line passes directly across the centre of the pit.—Father: Well, after you have fixed the pit on the paper, draw a line across it similar to the one you see in figure 16.

Son: I am quite able to do that, father, but what shall I do after?—Father: What you have next to do is this:—take your protracter and place it across the pit and line, after which, it will be similar to figure 17.

Son: Very good, father; I am able, also, to do that, as I see figure 17 is only a representation of figure 16, with a protracter added to it; but what have I to do, father, after fixing the protracter?—Father: You have only to look into your book (figure 15,) for the degrees from the pit to the cross-roads. Did you not make an entry there, of 63½ degrees from the pit to the cross-roads?

Son: Yes, the number of degrees are, I see (figure 15,) 63½, and the length of the road is 45 yards.—Father: All you have to do, then, is to count round from the north-end of the protracter until you come to 63½ degrees, and there make a pin mark (see P) in the side of the protracter.

Son: After I have done so, do I then take up the protracter? Father: Yes, and measure from the centre of the pit, forward in the direction of the pin point, the length of the road 45 yards, on a scale of, say 20 yards to the inch.

Son: After measuring the length of the road, will it represent something like figure 18? as I see the road extends beyond the pin mark P.—Father: Yes, and by this you have got the pit, and the first length upon the plan.

Son: I can see very well, father; I want the cross-roads; now what have I to do next to lay them on the plan?—Father: All you have to do is simply to make another line with your pencil across the end of the road similar to that across the pit. This line must be parallel to the one across the pit; to make a correct line you will require a parallel ruler. See figure 19.

Son: Figure 19, I see, is only a representation of figure 18, with a parallel ruler upon it, which ruler must be opened out until a line can be drawn across the end of the road; and what is there to do after this, father?—Father: You have to take your protracter again, and place it across the road, placing it in a similar manner as you did across the pit (see figure 17).

Son: When I have done so it will, I see, represent something like figure 20, as the protracter is upon the line N and S.—Father: Such is the case. You will have to look again for the degrees in your book (figure 15); there are for one road 61, another 152, and the third road is 332½; such are the several degrees in each road.

Son: Then I presume, father, I have only to do as before, count round the protracter for the degree on each road, and make a pin mark at every degree?—Father: Yes, you count round the protracter until you come to 61, then make a pin mark at P, after which count again until you find 152, and there also make a pin mark at P. Count forward to 332½, and make another pin mark there.

Son: Very good, father. I see all the pin marks around the edge of the protracter; do I now lift off the protracter?—Father: Yes. You take off the protracter, which will (after you have done so) be similar to figure 21. See all the pin marks P.

Son: Well, father, I think I can see a little how planning is accomplished; I have only to measure separately each of the roads, measuring from the end of the road direct to each pin mark. The measurement of one road is forty yards, or two inches on the plan; the other roads are twenty-four yards and twenty-two yards.—Father: That is the way; make the length of each road according to the scale, and also according to the number of yards you have entered in your book.

Son: When I have got the length of each road on the plan, it will, I see, be like figure 22?—Father: Yes, it will; you must continue to lay the workings on the paper until the whole of them are finished.

Son: I may, I presume, father, in a similar manner lay fields, boundaries, &c., if I only commence, say at the pit, and look towards such objects?—Father: Yes; you may in the same manner lay on the plan, any boundary or field, if only the pit be the object at which you commence; you first lay the pit on the plan, and therefore it must be the object to commence from to find others.

Son: I am very glad, father, for a knowledge of dialling, and also of laying the workings of a mine on a plan. I wish now to understand the mode by which I may take the dip and rise of the mine?—Father: It is my intention to give you that information also. You see figure 23, which is a representation of the dial; on the dial cover you will find figures similar to those in figure 23; you will also find in the cover two holes as represented in figure 23. All you have to do is to fix a peg as in figure 23, with a string to which a weight is suspended.

Son: Shall I not have to fix the dial on one side, and look through the sights when it is bent down?—Father: Yes; and when you look through the sights at objects downwards or upwards, so will you be able to find the degree of such dip or rise of the mine.

Son: I see, father, the string on the dial cover is at 17; do I understand that to be 17 degrees?—Father: Just so. The mine dips at an angle of 17 degrees. All mines do not dip so much; some dip more, others much less; 17 degrees is about the dip here (St. Helens.)

Son: Do I lay the dip of the mine on a plan similar to the one of the underground workings?—Father: Yes. All you have to do is to make a straight line on your plan, and call the straight line the level surface (see figure 24), place your protracter upon this line, and count round to 17, make a pin mark there, and then take up the protracter.

Son: Then I see the dip of the mine will be shewn in the same manner as in figure 24?—Father: Just so. You will now, I think, understand how to take the dip and rise of the mine.

Miscellaneous Questions.

Son: I have a few miscellaneous questions, father, to ask, which, no doubt, you will try to answer.—Father: What are they?

Son: I wish to know how you find the area of, and the number of cubic feet in, a circular pit, or in a circular air-gate? Father: I do it in the following manner:—Measure across the pit or circle, and multiply the distance or diameter by itself; multiply again by 7854, and then strike off the four last figures of the result in the manner below described. Find the area and also the cubic contents of a pit 12 feet in diameter and 365 feet deep.

The diameter of pit	12
Multiplied by itself	12
	144
Again multiplied by	.7854
	576
	720
	1152
	1008
Area of pit	113.0976
Multiplied by depth of pit	365
	5654880
	6785856
	3392928
Cubic contents	41,280.6240

Thus the area, you see, is 113 feet and very near one-tenth of a foot.

Also, the cubic contents are 41,280 feet, and 6-10ths of a foot for the pit, being 12 feet in diameter and 365 feet deep.

Son: I may find the cubic feet, then, father, of any circular pit, or circular air-passage, by this mode, be it less or more? Father: Yes, you will have to adopt the said mode of measurement, whether the diameter be in inches or in yards. If the diameter of the pit had been 12 inches, and the depth 365 inches, the result would have been the same in inches, or in yards, as the case may be. To find the cubic contents of an air-passage not circular, multiply the length of it by the area. Thus the length of the passage may be, say sixty feet, by five feet wide and four feet high.

60 long.
5 wide.

300
4

1200 cubic feet area.

According to the late Dr. Glover, 666 cubic feet of air will sustain a healthy man for twenty-four hours; if so, an air-passage of 1,200 feet would sustain a man, if full of pure air, forty-three hours.

Son: Have you any knowledge, father, of what power is produced when a quantity of gas is ignited? that is, do you know what gas is capable (in proportion to its quantity) of propelling before it?—Father: I know the power of gas, when ignited, is very great, as may be seen often in mines after explosions. At the Hetten colliery explosion, December 20, 1860, it was supposed that the explosion had been caused by a flue, containing about 7,000 cubic feet, becoming filled with gas, which afterwards ignited. The scientific and chemical evidence given by Mr. Isaac Lowthin Bell, and Dr. Thomas Richardson, was this:—Supposing the 7,000 feet to be exploded, it would become 56,000 feet, which would immediately be converted into after-damp. The temperature of these exploded gases being about 1,500 degrees of Fahrenheit, or a bright red heat, the power would be equal to 75 quarter casks of gunpowder, of 25lbs. each; that is, an explosion of 1,875lbs. of gunpowder. So you may judge by this the power of an explosion.

Son: Do not people say explosive gas cannot be destroyed?

Father: Yes; but it is well known to many, that gas in a stocked place, has often exploded in the safety-lamp, and after the place has been filled with tobacco-smoke, naked lights have been used shortly after with safety; and, if the quantum of gas be above the explosive mixture, the gas will extinguish the tobacco in the pipe.

Son: Suppose much wind, father, passes around the place where a miner is working, is he to know by this that his place is safe from explosions?—Father: No; unless his knowledge is such as enables him to know the purity of the wind; as the safety of his place is not in proportion to the quantity of wind, but, in proportion to the purity.

Son: If the same quantity of wind passes around his place every day, is he to know by this, that his place is safe from explosions?—Father: No; his place may not be safe then, because a change of the weather will cause a larger accumulation of gas at one time than at another; and if a larger quantity of gas accumulates, the wind will be more impure at one time than at another.

Son: But, suppose the miner can only see a little gas in the air which passes around his place; can he know it to be safe? Father: No; he cannot then say his place is safe, unless he has a knowledge of the several degrees of the impurity of the wind; because, if gas be pure, very little will be seen before it explodes; therefore, he should have a knowledge of the quality as well as the quantity of the gas, to have a proper knowledge of the safety of his place.

Son: Suppose you had two pits, father, one, say of 113 feet area, and the other of only 78 feet area, which of the two, the larger or the smaller, would you make into an up-cast?—

Father: The large one would make the best up-cast, because the air expands on account of the high temperature of the mine in passing through the workings to the up-cast; and from gases being added in the air from the strata, space would be required in the shaft for such expansion, otherwise, the velocity of the air in the up-cast would be greater than in the down-cast; and if the velocity be greater, the friction would be greater; the said quantum of air cannot ascend up the shaft as it would do if the shaft were larger in proportion to the expansion of the air, because, the friction would impede the ascent of the air, as a weight to a balloon would impede its ascent; for air is not propelled upwards out of a mine, but ascends like a balloon, of itself. The ascent of the said air being in proportion to its diminished lightness caused by its expansion.

Son: Suppose the coal in the workings should dip or rise, would the furnace produce the same quantum of air, if the up-cast shaft was fixed in one part of the royalty as in another? Father: The same power of a furnace would produce more air if the up-cast was fixed in an elevated position; because, as before stated, the air expands in passing through the workings; and this being the case, ascends and not descends. It therefore follows, that if a furnace be fixed where the shaft is, in an elevated position, so that the air in passing through the workings may ascend, and not descend, it will produce a larger quantity of air than one of the same power which is not fixed in such a position; because, in a furnace so fixed, the air will assist the furnace, as it ascends through the mine to the up-cast, but will not do so if it be caused to descend in passing to the up-cast. You may cause air to descend against the nature of what it would do, like two horses pulling against each other, the strong one would pull away the other; so in like manner, a larger furnace would be required than needful.

Son: Do you know, father, what quantity of air is produced in mines per minute?—Father: The quantity produced is not alike at all mines, in some more, and others less. The following will give you a knowledge of what has been produced in some mines.

Durham............	Hetton Colliery...	190,000	cubic ft.	per min.
Northumberland.	Wallsend do. ...	120,000	„	„
Yorkshire.........	Ardsley Main do.	80,957	„	„
Do.	Lund-hill do. ...	50,000	„	„
Derbyshire	Speedwell do. ...	40,000	„	„

Son: I thank you for the information, father, on mines. I had no idea our conversation would have continued so long, yet I am glad that it has done so, as I have now more information than I had before, for which I am thankful.—Father: My object in my life is to do all the good I can. I take a pleasure in doing so—in putting, if possible, the right man in the right place; in helping those who cannot help themselves; and in giving knowledge to those who require it. You have got now a knowledge of gases; how they accumulate in mines; why one mine accumulates more gas than another; the cause of some mines accumulating a mixture of gases; how it is that a change in the weather affects the workings of a mine; the power of an explosion of fire-damp, and how to diminish the power and cause; why air is propelled down and around the workings of a mine; several modes of ventilation; the danger of one mode and the safety of another; the friction of the air in mines; the great friction produced by one mode of ventilation, and how it may be reduced by another; several ways by which friction is produced; the power of the furnace, and the quantity of air produced by an increased power; several modes by which coal is worked out in mines; why so many ways are adopted; and also of who are the best and most competent persons to manage the underground workings of mines; the mode of dialling, and also laying the workings on a plan. I must now, my son, draw to a close. I hope what I have said you will inwardly digest, so that my labour bestowed upon you may not be in vain. If I have been successful, I shall be well rewarded, my object being only to give you information. I would beg of you, if ever you have charge of the under-ground working of mines, to do that which is right, as far as is in your power, both to the employer and the employed. Give to every person his right and due. Do not give away your master's money unless you have labour equivalent for it, as his money is not yours. Neither give away the workmen's labour to the master, for by so doing you rob them of their rights and living. Do to each as you would wish each to do to you. Study to be upright in all your dealings with every person, remembering that life will only be of short duration, so that you may be found right for the life to come.

Son: It is your will, I know, father, for me to do what is right and just, and I hope it will always be my endeavour to do so; if not, I may expect to be beaten with many stripes.—Father: If all people go astray, you are not justified in doing wrong. Never take advantage of a person because his profession of religion be not the same as yours; if he is sincere in his worship, look upon him as a friend and brother.

SUMMARY

OF

SERIOUS ACCIDENTS SINCE THE YEAR 1658.

DATE.	COLLIERY.	CAUSE.	LIVES LOST.
1658 May	Gallow Flat, near Elswick	Inundated	Unknown
About 1710	Bensham	Exploded	70 to 80
1743 Jan. 18	North Biddick	Do.	17
1757 June 10	Ravensworth	Do.	16
1766 Mar. 18	Walker	Do.	10
—— April 16	South Biddick	Do.	Several
1767 Mar. 27	Fatfield	Do.	39
1773 Dec. 6	A Colliery near the Wear	Do.	Several
1778 Dec. 8	Dolly Pit, Chaytor's Haugh	Do.	24
1793 Dec. 27	Hope Pit, Sheriff Hill	Do.	Several
1794 June 9	Rickleton Pit, near Picktree	Do.	30
—— June 11	Harraton	Do.	28
1794 Dec. 21	Hope Pit, Sheriff Hill	Do.	Several
1795 April 24	Paradise or West Pit, Benwell.	Do.	11
1799 Oct. 11	Lumley	Do.	39
1803 Sept. 25	Wallsend	Do.	13
1805 Oct. 21	Hebburn	Do.	35
—— Nov. 29	Exclose	Do.	38
1806 Mar. 28	Killingworth	Do.	10
1809 Sept. 14	Killingworth	Do.	12
1812 May 25	Felling	Do.	92
—— Oct. 10	Herrington Mill Pit, Pensher	Do.	24
1813 Sept. 23	Hall Pit, Fatfield	Do.	32
—— Dec. 24	Felling	Do.	22
1814 Aug. 12	Hebburn	Do.	11
1815 May 3	Heaton Main	Inundated	75
—— June 2	Success Pit, Newbottle	Exploded	57
—— June 27	Sheriff Hill	Do.	11
—— July 31	Newbottle	Bursting of the boiler of a high pressure locomotive engine.	18

DATE.			COLLIERY.	CAUSE.	LIVES LOST.
1817	June	30	Row Pit, Harraton	Exploded	38
——	Dec.	18	Plain Pit, Rainton	Do.	27
1819	July	19	Sheriff Hill	Do.	35
——	Oct.	9	George Pit, Lambton	Do.	13
1821	Oct.	28	Wallsend (Russell's)	Do.	52
1823	Nov.	3	Plain Pit, Rainton	Do.	59
1824	Nov.	19	Dolly Pit, Newbottle	Do.	11
——	Oct.	25	George Pit, Lumley	Do.	14
1825	July	3	Judith Pit, Fatfield	Do.	11
1826	Jan.	17	Jarrow	Do.	34
——	May	30	Townley	Do.	38
1828	Nov.	20	I Pit, Washington	Do.	14
1830	Aug.	3	Jarrow	Do.	42
1832	June	15	Newbottle	Boiler exploded	12
1833	May	9	Springwell	Exploded	47
1835	June	18	Wallsend	Do.	102
1836	Jan.	28	Hetton Colliery	Do.	20
1839	June	28	Hilda Wallsend, South Shields	Do.	50
1840	Jan.	24	Rothwell Haigh, Leeds	Do.	7*
1844	Sept.	28	Haswell	Do.	95
1845	Aug.	21	Jarrow Colliery	Do.	39
1850	Nov.	11	Houghton	Do.	26
1851	Mar.	15	Nitshill, Scotland	Do.	61
——	Aug.	19	Washington	Do.	28
——	Oct.	31	Killingworth	Do.	9
1852	May	—	Hebburn	Do.	23
1855			Middle Duffryn	Do.	68
1857	Feb.	19	Lundhill	Do.	189
1860	Mar.	2	Burradon	Do.	74
——	Dec.	7	Risca, South Wales	Do.	180
——	Dec.	20	Hetton	Do.	22
1861	July	—	Clay Cross	Inundated	23
1862	Jan.	16	Hartley	By breaking of engine pump beam.	204
——	Mar.	—	Gethin	Exploded.	47
——	June	2	Bilston	Inundated.	7

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* At this colliery the father of William Hopton, the author of this book, was lost.

TABLE OF WEIGHTS AND MEASURES.

THE origin of all *Weights and Measures* in England was derived from a grain of wheat; vide Statutes of 51 Henry III., 31 Edward I., and 12 Henry VII., which enacted that 32 of them, well dried and gathered from the middle of the ear, were to make 1 pennyweight; 20 dwts. 1 ounce; and 20 oz. 1 pound.

It was subsequently thought better to divide the *pennyweight* into 24 equal parts, called *grains*.

William the Conqueror introduced into England what was called TROY WEIGHT, from Troyes, a town in the province of Champagne, in France, now in the department of Aube, where a celebrated fair was held. The English were dissatisfied with this weight, because the pound did not weigh so much as the pound in use at that time in England. Hence arose the term, *Avoir du poids*, which was a medium between the French and the ancient English weights.

AVOIRDUPOIS WEIGHT was first made legal in the reign of Henry VII., and its particular use was to weigh provisions and coarse heavy articles. Henry fixed the stone at 14 lbs., which has been confirmed by a recent Act of Parliament.

With respect to MEASURES OF LENGTH, it is recorded that the various denominations were constructed from a *corn of barley*, 3 of which, well dried, from the middle of the ear, made an inch. Other terms were taken from portions of the human body, such as the *Digit* ($\frac{3}{4}$ of an inch, or a finger's breadth), a *Palm* (3 inches), a *Hand* (4 inches), a *Span* (9 inches), a *Foot* (12 inches), and a Cubit (18 inches), being the length of the arm or bone from the elbow to the wrist. A *Pace* (5 feet), or 2 ordinary steps; a *Fathom* (6 feet), from the extremity of one hand to that of the other, the arms oppositely extended. It is stated that Henry I., in 1101, commanded that the ulna, or ancient ell, which answers to the modern yard, should be made the length of his arm; and that the other measures of length were hence derived, whether *lineal*, *superficial*, or *solid*.

All MEASURES OF CAPACITY were first taken from Troy Weight, and several laws were passed in the reign of Henry III., enacting that 8lbs. Troy of wheat, taken from the middle of the ear, and well dried, should make one gallon of Wine measure, and 8 such gallons make a bushel.

Weights and measures were invented 869 B.C.; fixed to a standard in England, A.D. 1257; regulated, 1492; equalized, 1826.

Agreeable to the Act of Uniformity, which took effect 1*st Jan.*, 1826.

The term *Measure* may be distinguished into seven kinds, viz.—*Length*, *Surface*, *Volume*, *Specific Gravity*, *Capacity*, *Space*, and *Time* and *Motion*.

The several Denominations of these Measures have reference to certain *standards*, which are entirely arbitrary, and consequently vary among different nations. In this kingdom, the *Standard* of

Length is a *Yard.*
Solidity is a *Cubic Yard.*
Surface is a *Square Yard*, the 1 48–40 of an Acre.
Capacity is a *Gallon.*
Weight is a *Pound.*

The standards of *Angular Measure* and of *Time* are the same in all European and most other countries.

The *Imperial Standard Yard*, and the *Imperial Standard Pound Troy* having been destroyed in the fire at the Houses of Parliament in 1834, *Restored Standards of Weights and Measures* have been legalized by 18 and 19 Vic., cap. 72.

I.—Measures of Length.

The *Restored Standard* of Lineal Measure, whose length is called a yard, is a solid square Bar, Thirty-eight Inches long and One Inch Square, in Transverse Section, the Bar being of Bronze or Gun Metal, at the Temperature of 62° of Fahrenheit's Thermometer—marked Copper 16 oz., Tin 2½ oz., Zinc 1 oz.—and near to each end a cylindrical hole is sunk, to the depth of half an inch; the distance between the centres of the two holes being 3 *Feet* or 36 *Inches*, or one *Imperial Standard Yard.* The standard *square* and *cubic* measures will therefore depend entirely upon it.

At present we have no means of ascertaining why this particular length was originally fixed upon; but as it is most essential that it should always remain the same, it will be found convenient to refer it to something else, which we have no reason to suppose ever undergoes any change.

Now the length of a *Pendulum* vibrating *seconds*, or performing 86,400 oscillations in the interval between the sun's leaving the meridian of a place and returning to it again, is always the same at a *fixed* place and under the *same* circumstances; and if this length be divided into 391,392 equal parts, the yard is *defined* to be equivalent to 360,000 of these parts: also, conversely, since a yard is equal to 36 inches, it follows that the length of the seconds' pendulum, expressed in inches, is 39·1392.

The *Pendulum* referred to in this country, is one vibrating seconds at *Greenwich* or in *London*, at the level of the sea in a non-resisting medium; and if the *standard yard* be at any time lost or destroyed, it would be easy to have recourse to experiment for its recovery.

The *standard Yard*, being the general *Unit* of lineal measure, it follows that all lengths less than a *yard* will be expressed by fractions; and it is on this account that a lineal *inch*, or *ten thousand* of the aforesaid portions of the *pendulum*, is conveniently adopted as the *unit* of lineal measure when applied to small magnitudes.

Hence also, by the same means, the *standard superficial* and *solid* measures will be accurately ascertained and kept correct.

LINEAL MEASURE.

12 Inches .... = 1 Foot (ft.)
3 Feet .... = 1 Yard (yd.)
5½ Yards........................ = 1 Rod, or Pole (po.)
40 Poles or 220 Yards .... = 1 Furlong.
8 Furlongs or 1760 Yards ... = 1 Mile.

By this measure are computed the lineal dimensions of all magnitudes, with the exception mentioned below.

The *length* of a mile is not the same in every country. The Scotch and Irish miles were formerly about 1¾ English, but are now the same as English. A Spanish and Polish mile is about 3½ English. A Swedish, Danish, and Hungarian mile is from 5 to 6 English miles. A Russian mile or verst is about ¾ of an English mile ; and the French toise is about 6 feet.

The Dutch mile.............................. = 8101 Yards
Roman .... = 1628 „
Arabian .... = 2148 „
Persian parasang .... = 6086 „
1–12 Inch............................ = 1 Line
⅓ Inch .... = 1 Barleycorn
3 Inches .... = 1 Palm
4 Inches .... = 1 Hand*
7 23–25 Inches .... = 1 Link
9 Inches .... = 1 Span
18 Inches .... = 1 Cubit
2½ Feet............................ = 1 Pace†
5 Feet (a geometrical) .... = 1 Pace
6 Feet............................ = 1 Fathom‡
5½ Yards .... = 1 Rod, Pole, or Perch
4 Poles or 22 yards .... = 1 Chain
3 Miles .... = 1 League

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* The *Hand* is used for measuring the height of horses.

† The *Pace* is a measure taken from the space between the two feet of a man in walking, usually reckoned at 2½ feet, but the *Geometrical Pace* is 5 feet.

‡ The *Fathom* is used in sounding to ascertain depths, &c., and for measuring cordage.

60 Geographical miles, or 69½ English miles .... = 1 Degree (or °)
360 Degrees .... = The circumference of the Globe, or any Circle

CLOTH MEASURE.

This measure is used for all kinds of cloth, muslin, ribbon, &c.

The *Yard* in Cloth Measure is the same as in Long Measure, but differs in its divisions and subdivisions.

2¼ Inches.......................... = 1 Nail
4 Nails .... = 1 Quarter
4 Quarters .... = 1 Yard
8 Quarters .... = 1 Flemish Ell
5 Quarters .... = 1 English Ell
6 Quarters .... = 1 French Ell

II. Measures of Surface.

The *Imperial square yard* contains 9 imperial square feet, and the *Imperial square foot*, 144 imperial square inches; the *circular foot* (that is, a circle whose diameter is 1 foot) contains 113·097 square inches; and the *square foot* contains 183·346 circular inches (that is, circles whose diameters are each 1 inch.)

SUPERFICIAL MEASURE.

144 Sq. Inches.................. = 1 Sq. Foot.
9 Sq. Feet..................... = 1 Sq. Yard.
30¼ Sq. Yards .... = 1 Sq. Pole.

This measure is used for all kinds of superficies measuring, such as land, paving, flooring, roofing, tiling, slating, plastering, &c., and anything having length and breadth only.

Flooring, roofing, thatching, &c., are measured by the square of 100 feet, and bricklayers' work by the pole of 16½ feet, the square of which is 272¼ feet, though this is partly a cubic measure, as the brickwork is reckoned to be 14 inches, or 1½ brick thick.

LAND MEASURE.

40 Sq. Poles .... = 1 Sq. Rood.
9 Sq. Roods, or 4840 Sq. Yards = 1 Sq. Acre.
640 Sq. Acres .... = 1 Sq. Mile.
30 Sq. Acres .... = 1 Yard of Land.
100 Sq. Acres .... = 1 Hide of Land.
40 Hides........................... = 1 Barony.

The dimensions of Land, or of any surface of considerable extent, are taken by means of *Gunter's Chain*, which is 4 poles or 22 yards in length, and is divided into 100 equal parts, called *links*.

III. Measures of Volume.

The *Imperial cubic* (or solid) *yard* contains 27 imperial cubic feet, and the *imperial cubic foot* contains 1728 imperial cubic inches. The *cylindric* foot (that is, a cylinder 1 foot long and 1 foot in diameter) contains 1357·17 cubic inches. The *Spherical* foot (that is, a sphere 1 foot in diameter) contains 904·78 cubic inches; and a *conical foot* (that is, a cone 1 foot in height and 1 foot in diameter at the base) contains 452·39 cubic inches. The *Cubic foot* contains very nearly 2200 cylindrical inches (that is, cylinders 1 inch long and 1 inch in diameter); it contains very nearly 3300 spherical inches (that is, spheres 1 inch in diameter), and it contains very nearly 6600 conical inches (that is, cones 1 inch in height and 1 inch in diameter at the base).

SOLID OR CUBIC MEASURE.

A *Cube* is a solid body, and contains length, breadth, and thickness, having six equal sides. A *cube number* is produced by multiplying a number twice into itself; thus, 64 is a cube number, and is produced by multiplying the number twice into itself, as 4 × 4 × 4 = 64.

1728 Cubic Inches.................. = 1 Cubic Foot.
27 Cubic Feet..................... = 1 Cubic Yard.
40 Cubic Feet of Rough or 50 Cubic Feet of Hewn Timber = 1 Ton or Load.
42 Cubic Feet of Timber ...... = 1 Shipping Ton.
108 Cubic Feet .... = 1 Stack of Wood.
128 Cubic Feet .... = 1 Cord of Wood.

The English foot is to the Paris foot as 1 to 1·065977.
The English Sq. foot is to the Paris as 1 to 1·136307.
The English cubic foot is to the Paris as 1 to 1·211277

IV. Standard of Specific Gravity.

The *Imperial pound avoirdupois*, which is the standard unit by means of which all heavy goods of large masses are weighed, is *defined* to be the weight of *one-tenth* part of an imperial gallon, or of 27·7274 cubic inches of distilled water, ascertained at a time when the barometer stands at 30° and the height of *Fahrenheit's* thermometer is 62°: and this standard may consequently be verified or recovered at any time, when it may be necessary to appeal to experiment.

If the weight of a cubic inch of distilled water be divided into 505 equal parts, and each of such parts be defined to be a *half-grain*, it follows that 27·7274 cubic inches contain very nearly 7000 such grains; and it is hence declared by Act of Parliament that 7000 *grains* exactly shall hereafter be considered as the *pound* avoirdupois; and that 10 *grains* shall be equivalent to 1 *scruple;* and 3 *scruples* to 1 *drachm;* but these latter denominations are seldom necessary unless great nicety be required.

This weight receives its name from *avoirs*, the ancient name for *goods and chattels*, and *poids* signifying *weight*, in the ordinary language of the country at the time of the *Normans*.

The *Restored Imperial Standard Pound Avoirdupois*, is constructed of Platinum, the Form being that of a *Cylinder* nearly 1·35 Inch in height, and 1·15 Inch in diameter, marked P.S., 1844, 1 lb.

DIVISION 1.—AVOIRDUPOIS WEIGHT.

$27\frac{11}{32}$ Grains = 1 Drachm ...... = $27\frac{11}{32}$ grains.
16 Drachms = 1 Ounce ...... = $437\frac{1}{2}$ grains.
16 Ounces = 1 Pound (lb.) = 7000
14 Pounds = 1 Stone.
28 Pounds = 1 Quarter (qr.)
4 Quarters = 1 Hundredweight (cwt.)
20 Cwt. = 1 Ton.

This weight is used in almost all commercial transactions, and in all the common dealings of life.

By an Act of Parliament passed the 5th of October, 1831, and which came into effect on the 1st of January, 1832, it is directed that all coals, cinders, and culm, sold from and out of any ship or vessel in the port of London, or at any place within the cities of London and Westminster, or within the distance of 25 miles from the General Post Office, in the city of London, should be sold by weight, and not by measure.

Coals sold in any quantity exceeding 500 lbs., are to be delivered to the purchaser in sacks containing either 112 lbs. or 224 lbs. net; 10 such sacks, or 2240 lbs., make a ton, equal to 20 cwt.; 25½ cwt. are equivalent to 1 chaldron. A barge load, or keel, is 21 tons 4 cwt.; and a collier, or ship load, about 20 such keels, or 424 tons.

By an Act of Parliament which came into effect on the 29th of September, 1822, bread must be sold by the pound avoirdupois, and bakers are prohibited from selling by the peck loaf with its subdivisions.

Flour is sold nominally by measure, but actually by weight, at 7 lbs. avoirdupois to a gallon, 14 lbs. to a peck, &c.

By a late Act of Parliament, the legal stone is, in all cases, to consist of 14 lbs. avoirdupois; 8 such stones 1 cwt.; 20 cwt. 1 ton.

V. Measures of Space.

A *Circle* contains 360 degrees; a *Degree* 60 minutes; a *Minute*, 60 Seconds, &c.; consequently a *Semi-circle* contains 180 degrees; a *Quadrant*, 90 degrees; a *Sextant* 60 degrees; and an *Octant*, 45 degrees, a *right angle* contains, or is measured by 90 degrees, and two right angles by 180 degrees. The *circumference* of a circle is nearly 3 1–7 times its diameter, or more accurately 3·1416 times; in other words, this number is the *circumference* of a circle, whose *diameter* is unity; consequently, the *diameter* of a circle is nearly 7-22, or more accurately ·31831 of its circumference. In France the *circle* is frequently divided into 400 degrees, a degree into 100 minutes, and a minute into 100 seconds, &c. The latter is called the *centesimal* system, and the former the *sexagesimal*; consequently, 1 centesimal degree contains 54 sexagesimal minutes; 1 centesimal minute, 32·4 sexagesimal seconds; 1 centesimal second, ·324 of a sexagesimal second; and also 1 sexagesimal degree contains 1 1–9 centesimal degree; 1 sexagesimal minute, 1·85185 centesimal minute; and 1 sexagesimal second, 3 08641 centesimal seconds. A mean *sexagesimal* degree of the terrestrial meridian measures 69·045 imperial miles.

ANGULAR MEASURE, OR DIVISIONS OF THE CIRCLE.

60 Seconds .... = 1 Minute
60 Minutes .... = 1 Degree
30 Degrees .... = 1 Sign
90 Degrees ... . = 1 Quadrant
4 Quadrants .... = 1 Circle
360 Degrees, or 12 Signs = 1 Circumference or great Circle.

VI.—Measures of Time and Motion.

A *Mean solar day* is the mean apparent time of one revolution of the earth on its axis; and it is divided into 24 hours; an hour into 60 minutes; and a minute into sixty seconds, &c.; hence the mean daily apparent motion of the sun is 15 degrees per hour, or 1 degree in 4 minutes of time. A *Sidereal day* is the real and invariable period of the diurnal rotation, and contains 23 hours, 56 minutes, 4 1-10 seconds of mean solar time. A *Tropical year* is the period of one revolution of the earth in its orbit, and contains 365 days, 5 hours, 48 minutes, 49·19 seconds of mean solar time. The seconds' pendulum makes 86,400 vibrations in a mean solar day at the same place on the earth's surface.

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